THE REPUBLIC OF TURKIYE
SOCIAL SCIENCES UNIVERSITY OF ANKARA
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ASSESSING THE ENERGY SOURCES OF GHANA AND THE IMPACTS OF THEIR USAGE ON THE ECONOMY AND ENVIRONMENT

Masters' Thesis

Muniratu DAUDA

Energy Economics and Management

November 2023

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ABSTRACT

This research investigates the interrelationship between energy use, economic growth, and environmental impacts in Ghana. Employing a combination of qualitative techniques, it scrutinizes the nation's energy landscape, delineating sources, consumption patterns and projections. The analyses unveiled escalating energy demand and greenhouse gas emissions over the past decade, underscoring sustainability challenges. Traditional biomass remains pervasively utilized for household needs, precipitating indoor air pollution and deforestation. Despite expanded electricity accessibility, high tariffs and unreliable supply adversely affect households and enterprises. Although fossil fuels dominate Ghana's energy portfolio, unexploited renewable potential exists. Integral recommendations encompass diversifying the energy mix through investments in solar, wind and hydroelectric power to mitigate emissions and reliance on biomass and imported oil. Additionally, targeted financing and subsidies could facilitate clean energy adoption among low-income populations. Robust legal frameworks, comprehensive energy policies and enhanced institutional coordination are vital to address existing limitations. Further academic inquiry should investigate the viability of renewable energy ventures, the impacts of energy subsidies and the potential for public-private partnerships. In summary, this research aimed to provide salient insights into Ghana's intricate energy landscape to inform policymaking and future scholarly efforts toward a sustainable energy future.

Keywords: Renewable Energy, Environmental Sustainability, Economic Impact, Energy Consumption, Energy Policy

OZET

Bu araştırma, Gana'da enerji kullanımı, ekonomik büyüme ve çevresel etkiler arasındaki karşılıklı ilişkiyi incelemektedir. Nitel tekniklerin bir kombinasyonunu kullanarak, kaynakları, tüketim modellerini ve projeksiyonları tanımlayarak ülkenin enerji alanını incelemektedir. Analizler, son on yılda artan enerji talebini ve sera gazı emisyonlarını ortaya koyarak sürdürülebilirlik sorunlarının altını çiziyor. Geleneksel biyokütle, ev ihtiyaçları için yoğun bir şekilde kullanılmaya devam etmekte, bu da iç mekan hava kirliliğine ve ağaçsızlaşmaya neden olmaktadır. Genişleyen elektrik erişimine rağmen, yüksek tarifeler ve güvenilmez tedarik hane halklarını ve işletmeleri olumsuz etkilemektedir. Fosil yakıtlar Gana'nın enerji portföyüne hakim olsa da, kullanılmayan yenilenebilir potansiyel mevcuttur. Entegre öneriler, emisyonları ve biyo-kütle ve ithal petrole bağımlılığı azaltmak için güneş, rüzgar ve hidroelektrik enerjisine yatırım yaparak enerji karışımını çeşitlendirmeyi kapsamaktadır. Ayrıca, katranlı finansman ve sübvansiyonlar düşük gelirli nüfus arasında temiz enerjinin benimsenmesini kolaylaştırabilir. Sağlam yasal çerçeve, kapsamlı enerji politikaları ve gelişmiş kurumsal koordinasyon, mevcut sınırlamaları ele almak için hayati önem taşımaktadır. Daha fazla akademik araştırma, yenilenebilir enerji girişimlerinin uygulanabilirliğini, enerji sübvansiyonlarının etkilerini ve kamu-özel sektör ortaklıklarının potansiyelini araştırmalıdır. Özet olarak, bu araştırma sürdürülebilir bir enerji geleceğine yönelik politika oluşturma ve gelecekteki akademik çabaları şekillendirmek için Gana'nın karmaşık enerji ortamına ilişkin önemli bilgiler sağlamayı amaçlamıştır.

Anahtar Kelimeler: Yenilenebilir Enerji, Çevresel Sürdürülebilirlik, Ekonomik Etki, Enerji Tüketimi, Enerji Politikası

ABBREVIATIONS

ACTC	African Climate Technology Centre
Btu	British thermal unit
CO2	Carbon Dioxide
EC	Energy Commission
ECG	Electricity Company of Ghana
ECOWAS	Economic Community of West African States
EIA	Energy Information Administration
EP	Energypedia
EPA	Environmental Protection Agency
ESCO	Energy Service Company
EU ETS	European Union Emissions Trading System
FAO	Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility
GD	Global Data
GDP	Gross Domestic Product
GHC	Ghanaian Cedi
GHG	Green House Gas
GNGC	Ghana National Gas Company
GNPC	Ghana National Petroleum Corporation
GREF	Ghana Renewable Energy Fund
GRERC	Ghana Renewable Energy Risk Capita
GRIDCo	Ghana Grid Company
GSS	Ghana Statistical Service
GWh	Gigawatt hours
IEA	International Energy Agency
IEA	International Trade Administration
IHA	International Hydropower Association
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency

ISD	Indicators for Sustainable Development
ITA	International Trade Administration
Ktoe	kilotonnes of oil equivalent
Kwh	Kilowatt hour
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
LUCF	Land Use Change and Forestry
MEPI	Multidimensional Energy Poverty Index
MoF	Ministry of Finance
MoP	Ministry of Power
MPRA	Munich Personal RePEc Archives
MtCO2e	Metric tons of carbon dioxide equivalent
MW	Megawatt
NEDCo	Northern Electricity Distribution Company
NREAP	National Renewable Energy Action Plan
OWID	Our World in Data
PAYG	Pay as You Go
PURC	Public Utilities Regulatory Commission
PV	Photovoltaic
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
REF	Renewable Energy Fund
REMP	Renewable Energy Master Plan
SDG	Sustainable Development Goal
SEforAll	Sustainable Energy for All
SHS	Senior High Schools
SMEs	Small and medium-sized enterprises
SREP	Scaling-Up Renewable Energy Program in Ghana
SS	Sustainable Square
SSA	Sub-Saharan Africa
TOE	Tonne of oil equivalent
UN	United Nations
UN	United Nations
UNCSD	United Nations Commission on Sustainable Development

UNDESA	United Nations Department of Economics and Social Affairs
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VAR	Vector Auto regression
VRA	Volta River Authority
WB	World Bank
WHO	World Health Organization
WSSD	World Summit on Sustainable Development

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CHAPTER ONE

INTRODUCTION

1.1. Background

Aboagye (2019) suggests that human economic activities, in most cases, have negative impacts on the entire ecosystem, resulting in serious environmental issues such as floods, negative climate change, and natural resource depletion which if not well controlled could result in the loss of livelihoods and significant economic resources. Undoubtedly, the effort to grow the economy of Ghana has ultimately resulted in an increase in economic activity levels as well as an increase in urbanization and industrialization. Given the prevalent reliance on energy-centric resources within the modern Ghanaian economy, it is plausible that the observed trends have become intertwined with escalated levels of energy utilization.

According to Kwakwa et al. (2014), the economy as a whole relies on energy for the operations of the transport, manufacturing, agricultural, mining, construction, and public and commercial services sectors. Additionally, energy gives households a way to meet their basic needs for everything from cooking, lighting, heating, and washing to entertainment.

The fundamental nexus connecting energy and economic advancement becomes apparent through its pivotal contribution, particularly within the realms of industry, manufacturing, services, and even agriculture. The research conducted by Aboagye (2017) underscores that energy-centric resources and inputs constitute a substantial proportion of foundational industrial constituents in both advanced and developing nations, often assuming a critical role in the formulation of sustainable economic trajectories. Nevertheless, the heightened utilization of energy carries the potential to exacerbate environmental conditions, particularly within countries characterized by limited levels of ecological awareness and conscientiousness.

However, increased energy use has the potential to worsen the environment, particularly in nations with low levels of environmental awareness and concern. Hence, it is plausible to anticipate a steady augmentation in both energy consumption and requisition in the forthcoming years, attributed to the burgeoning global populace alongside expeditious trends of urbanization and industrial expansion. Although this phenomenon is remarkable and essential for economic growth, there is reason to be concerned about the serious effects that energy consumption may have on the value and sustainability of the environment (Kwakwa and Aboagye, 2014).

Furthermore, according to Brain Copeland and Scott Taylor (2003), there is little and inconsistent research on the effects of economic growth on the environment. This could rationally account for Ghana's lack of strict environmental policies, laws, and regulations as well as their inconsistent enforcement. Given the evidence that increased economic activity and energy consumption have also coincided with an increase in environmental degradation, including loss of biological diversity, climate change, increased air and marine pollution, desertification, and deforestation, particularly in many developing countries, it is essential to conduct a thorough empirical analysis to establish the connections between energy consumption or its intensity and the environment.

Thus, the purpose of this study is to investigate whether energy consumption influences environmental pollution. The study also investigates whether the advancement of technology could act as a catalyst to improve environmental quality. This study will help identify the impacts of the various energy sources on the environment which will inform stakeholders in this sector of the necessary steps to take to provide cleaner energy sources as well as protect the environment.

1.2. Problem Statement

In the pursuit of progress and the alleviation of impoverishment, the attainment of energy accessibility assumes paramount significance. Its indispensability is evident in its dual role in fostering economic endeavors and enhancing human welfare. The provision of cost-effective and environmentally sound energy stands as an imperative for the progression of commercial enterprises, communication networks, agricultural activities, educational systems, healthcare services, and transportation infrastructure, congruent with the objectives outlined in Goal 7. Notably, challenges about energy access pose hindrances to both the advancement of economies and the holistic development of individuals (UN, 21 November 2022).

The latest available data underscores ongoing advancements toward the attainment of sustainable energy objectives; however, the pace of current progress remains inadequate for the fulfillment of Goal 7 by the designated timeline of 2030. The accessibility to contemporary sustainable energy sources remains markedly disparate (UN, 21 November 2022). This inequality is glaringly manifested in the fact that a considerable 13% of the global population remains devoid of electricity access (OWID, 3 November 2022). A comprehensive evaluation conducted by the Energy Commission in 2017 reveals that, as of the conclusion of 2016, a noteworthy 83% of the populace enjoyed electricity access, leaving the remaining 17% compelled to rely upon conventional energy sources such as kerosene, wood fuels, and charcoal.

This is nearly twice as much access to power as there was in 2000 (43%) and roughly three and a half times as much as there was in 1990 (23%) (Bukari et al., 2021). With this, in Ghana, not every resident has access to electricity for domestic tasks like lighting, heating, and cooking. Some Ghanaians consider electricity to be a luxury and cannot afford it. The investigation by Serwaa et al. (2015) delves into the intricacies encompassing energy access, alongside the scrutiny of the proposed energy access indicators. Their scholarly inquiry further furnishes a concise survey of the diverse classifications of energy access indicators, culminating in a comprehensive assessment of Ghana's access to modern energy resources.

This evaluation is conducted through the lens of the energy access indicators that have been employed within the Ghanaian context. Kemausuor et al. (2011) conduct an evaluation encompassing the trajectories, strategies, governmental directives, and initiatives aimed at augmenting energy accessibility within Ghana. This analysis centers on pivotal facets such as electricity provisioning, cooking fuel distribution, and the integration of renewable energy reservoirs. The authors assert that while successive administrations have consistently accorded paramount importance to furnishing energy utilities as a cornerstone of national advancement, their investigation underscores that prior and contemporary policies and initiatives have encountered limitations in expediting the dissemination of energy services. This dearth of efficacy is especially pronounced within rural and peri-urban areas, where the demand for such provisions remains most pronounced.

Considering the above, this research sought to understand the relationship between the sources of energy and their environmental impacts during and after usage. It examines the variety of energy sources used in the country's various housing types and for various domestic tasks (cooking, heating, and lighting), as well as the effects of these practices on the vegetation of Ghana. The study will help policy makers to propose or make laws and policies to promote the use of more environmentally friendly energy sources.

1.3. General and Specific Research Questions

To meet the objectives of the study, this research seeks to answer the following questions:

RQ1: What is the relationship between energy consumption and the economy of Ghana?

RQ2: What is the relationship between energy consumption and the environment of Ghana?

1.4. AIM and Objectives of the Study

The study aims to explore the impacts of energy consumption on the economy as well as the environment. To identify the sources of energy available in Ghana. This is by determining the energy sources that are available in Ghana and the impacts they have on both the economy and the environment. Lastly, future predictions of energy trends in Ghana will be examined as well as policy proposals for the energy sector of Ghana.

1.5. Significance of the Study

Several studies have been done concerning the various sources of energy available in Ghana, however, there is limited literature on the environmental impacts of these energy sources on both industries and residents. This study will help identify the impacts of the various energy sources on the environment as well as the economy which will inform stakeholders in this sector of the necessary steps to take to provide cleaner energy sources as well as protect the environment.

1.6. Study Area

Ghana, also known as the Republic of Ghana, is a sovereign nation. It is situated in the West of Africa, close to the Atlantic Ocean. As per the findings of the 2010 population and housing census, officially disclosed by the Statistical Service of Ghana in May 2012, the current population of Ghana stands at 24 million individuals, indicating a notable rise from the 18 million counts documented in 2000. The population growth rate is approximated at 2.2%. Notably, the urban populace constitutes 51% of the total population, showcasing a discernible alteration in the growth rate at 3.4%. In 2017, there were approximately 126.72 people per square kilometer in the entire country (WB, 15 March 2023). The current population of Ghana in 2023 is 32,818,669 million.

The main economic sector in Ghana is agriculture, which in 2012 accounted for 23% of the country's GDP. In Ghana, the agricultural sector provides employment for 53.6% of the country's population, while the remaining 46.4% of people find work in the manufacturing and service sectors. The 2021 figures for Ghana's GDP and GDP Per Capita were 77.59 billion and 2,363.3 US dollars, respectively (WB, 07 May 2023). Accra serves as the capital and most populous city of Ghana, accommodating approximately 1.96 million residents. The second-largest urban center within Ghana is Kumasi, housing around 1.47 million inhabitants. As for the third-ranking municipality by size, Tamale boasts a collective populace of 360,579 individuals (Ghana Statistical Service, 2021). The illustration presented below delineates Ghana's administrative divisions.

Figure 1.1. Administrative Map of Ghana

(Source: MG, 07 May 2023)

1.7. Research Framework

Chapter 1 of the thesis introduces an analytical background. Chapter 2 discusses the literature review to highlight the important issues in the work. The literature review presents details on various energy uses and their environmental impacts. Chapter 3 describes the relationship between energy use and the impacts it has on the Ghanaian economy. The relationship between energy use and its environmental impacts is also captured in chapter 4. Chapter 5 described as the descriptive analysis of energy issues in Ghana. The last aspect of the thesis contains the recommendations and conclusion of the work. Policy suggestions and future research proposals are also presented here.

CHAPTER TWO

LITERATURE REVIEW

2.1. Energy History of Ghana

From 1957, just before Ghana's pre-independence, to 1980, the country's energy sector underwent significant changes. Ghana changed during this time from a colonial era with little energy infrastructure to one with more emphasis on energy production and use. Ghana's colonial-era energy sources and practices were primarily characterized by restricted access to contemporary energy sources. There was little investment in the local energy infrastructure because the colonial authorities were primarily concerned with extracting and exporting natural resources (SS, 11, June 2023). As a result, traditional biomass sources like firewood, charcoal, and agricultural waste dominated the energy landscape. These energy sources were easily accessible and mainly used for domestic heating, light industrial use, and cooking. However, their poor efficiency and negative environmental effects posed serious problems. During this time, traditional biomass was primarily used in Ghana to meet its energy needs. Cultural customs and a lack of substitutes both contributed to the reliance on traditional biomass. For domestic cooking, Ghanaian communities relied heavily on firewood and charcoal, particularly in rural areas where access to modern fuels was limited. While traditional biomass could be used to meet short-term energy needs, it also led to environmental damage and deforestation. As population and energy demands grew, concerns about the sustainability of this energy practice grew (Adu-gyamfi, 2020). Ghana's energy sector underwent a significant transformation during this time, transitioning from heavy reliance on conventional biomass to the early development of hydroelectric power. This change signaled a turning point in Ghana's search for contemporary energy sources, addressing the drawbacks of using biomass while fostering sustainable economic development. Future developments in the energy sector were made possible by the construction of the Akosombo Dam and the creation of the VRA, which also prepared the way for further growth and diversification of Ghana's energy mix.

The country's energy sector underwent significant development from 1957, when Ghana gained independence, to 1980. The nationalization of energy assets, the creation of the Volta River Authority (VRA), the building and significance of the Akosombo Dam, the astounding expansion of hydroelectric power generation, and the introduction of thermal power plants were all hallmarks of this period. This period is generally termed as the Post-Independence era of the energy history of Ghana (Kipkoech et al., 2022). Following its independence, Ghana understood how crucial it was to regain control over its energy supplies and lessen its reliance on outsiders. To enhance national energy production self-sufficiency and consolidate ownership, the government began a process of nationalizing energy assets as part of this vision. Ghana aimed to foster economic growth and supply its citizens with affordable and dependable energy by placing significant energy assets under state control.

The Volta River Authority (VRA), a state-owned organization tasked with utilizing the nation's hydroelectric potential, was established by the government in 1961. The VRA assumed control of the ambitious project to build the Akosombo Dam on the Volta River and played a significant role in shaping Ghana's energy system. This dam, which was finished in 1965, had an impact on the development of the entire nation in addition to transforming Ghana's energy industry (IHA, 12 June 2023).

The Akosombo Dam construction was a remarkable engineering achievement. Beyond generating electricity, the dam's importance included facilitating irrigation, navigation, and the construction of Lake Volta, one of the biggest artificial lakes in the world. As a result of the increased food production and support for rural development made possible by Lake Volta, it became an essential water source for agricultural activities. Apart from that, Ghana was able to export energy thanks to the dam's hydropower capacity, which it used to power neighboring nations like Togo and Benin (Miescher, 2021). During this time, the expansion of hydroelectric power production was a major concern.

The capacity of the Akosombo Dam was gradually increased, and new hydroelectric power plants were built all over the nation. As a dependable and long-lasting energy source, hydroelectricity has emerged, giving Ghana a strong base for industrialization and economic development. The government's dedication to building out the hydroelectric infrastructure, along with the abundance of water resources, pushed Ghana in the direction of energy security and development (Miescher, 2021).

The government understood the need for a variety of energy sources to supplement the hydroelectric capacity. As a result, Ghana experienced the development of thermal power plants during this time. These facilities generated electricity using fossil fuels, mainly gas and oil. In addition to providing flexibility in meeting energy needs, thermal power plants acted as a fallback during times of low water flow or hydroelectric facility maintenance. They were essential in ensuring a steady flow of electricity and assisting Ghana's expanding business sectors and urban centers (ITA, 12 June 2023). Ghana's energy independence and economic growth were significantly influenced by the post-independence development of thermal and hydroelectric power infrastructure. Combining these two energy sources produced a dependable and well-balanced energy mix that encouraged domestic industrialization and reduced reliance on foreign energy sources. Ghana developed into a regional energy powerhouse, supplying electricity to its neighbors and promoting regional cooperation (Adusah-Poku et al., 2022).

2.2. Economic History of Ghana

Ghana's economy was heavily dependent on the production and export of basic goods like gold, cocoa, and timber during the colonial era. The British set up a taxation system that promoted the growth of cash crops for export at the expense of other areas of the economy. The economy became more susceptible to outside shocks due to its over-reliance on exporting raw materials, such as changes in raw material prices on the international market (UNECA, 10 May 2023).

Ghana's economy was primarily agricultural and centered on the production and export of cash crops like cocoa and gold during the colonial era. Foreign interests dominated the nation's economy, which saw little investment in industrialization or infrastructure. The first President of Ghana, Kwame Nkrumah, began an ambitious "Seven-Year Development Plan" of industrialization and modernization after the country gained independence in 1957. With a focus on consumer goods production, infrastructure development, and investments in education and healthcare, the plan sought to industrialize Ghana's agriculturally-based economy(Hymer, 1970). The Seven-Year Development Plan's implementation, however, was hampered by a number of issues, including political unrest, crime, and poor economic management. Ghana's economy was in crisis by the 1970s due to high inflation, low productivity, and a significant debt load. The government responded by enacting a number of economic reforms, such as devaluing the currency, liberalizing trade and investment, and privatizing state-owned businesses (Office of Planning Commission, 1964). Through increased funding for infrastructure, the privatization of state-owned businesses, and the liberalization of trade and investment, these reforms paved the way for a period of economic growth and stability in the 1980s and 1990s. This growth was, however, unequal, with a sizable rural-urban divide and enduring poverty in many regions of the nation. The National Poverty Reduction Program, the Ghana Poverty Reduction Strategy, and the Livelihood Empowerment against Poverty Program were among the government's responses (IMF, 10 May 2023).

Ghana's economy has been growing significantly in recent years thanks to increased infrastructure spending, the expansion of the oil and gas industry, and the expansion of the services industry. However, several problems, such as increasing debt, significant inequality, and enduring poverty in many areas of the nation, have come along with this growth. The Ghana Shared Growth and Development Agenda, Ghana beyond Aid Agenda, and the Planting for Food and Jobs program, among others, have all been put into place by the government to address these issues (MoF, 10 May 2023). To sum up, Ghana's economic past has been influenced by a multitude of factors such as colonialism, the struggle for independence, economic mismanagement, and the implementation of various policies and interventions throughout the years. Despite the significant progress made in recent times, there are still several obstacles to overcome in order to achieve long-term and equitable economic growth.

2.3. Stakeholders of the Ghanaian Power Sector

The Ministry of Power (MoP) oversees creating policies and overseeing some of their implementation. The economic and technical regulators of the energy sector are the Public Utilities Regulatory Commission (PURC) and the Energy Commission (EC), respectively. Ghana's power sector is decentralized and made up of state-owned utilities (Irena, 2015). The EC bears the responsibility for formulating and overseeing technical regulations that oversee various aspects of the power sector. This encompassing role encompasses activities such as the granting of operational licenses to industry operators and furnishing the Ministry of Energy with expert counsel on matters pertaining to power distribution and scheduling. Conversely, the Public Utilities Regulatory Commission (PURC) functions as an impartial regulatory entity vested with the task of enforcing economic directives within the power industry. Specifically, its jurisdiction pertains to the endorsement of electricity pricing schemes utilized by distribution utilities for the general public (EC and PURC roles outlined as per provided information). PURC is also responsible for keeping an eye on the superior electricity services provided to its customers (Energy Commission of Ghana, 2020)

The Volta River Authority (VRA) and Bui Power Authority are the generation utilities. Transmission and distribution are handled by Independent Power Producers (IPPs) and Ghana Grid Company (GRIDCo), the Electricity Company of Ghana (ECG), and the Northern Electricity Distribution Company (NEDCo) (Irena, 2015).

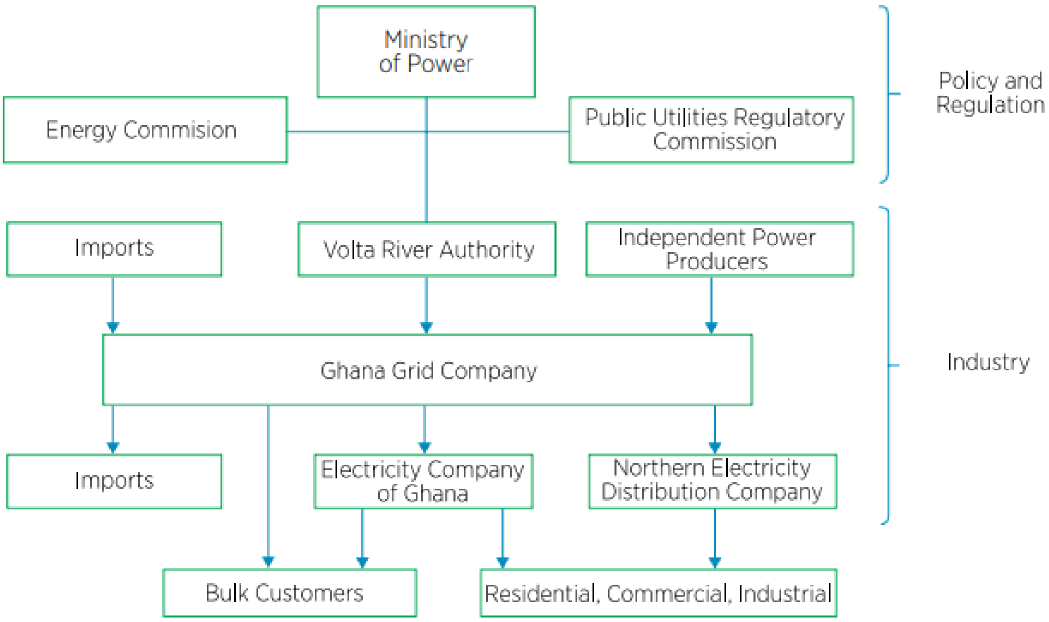

Figure 2.1. Stakeholders of the Power Sector in Ghana

(Source: Energy Commission of Ghana)

2.4. Current Energy Profile of Ghana

The population of Ghana is approximated at 31 million individuals, having exhibited an annual population growth rate of 2.2 percent since the year 2016. Paradoxically endowed with ample natural resources, the nation is grappling with severe deficits in energy availability. From the perspectives of both economic expansion and the establishment of essential infrastructure, Ghana falls within the category of a developing nation characterized by low-income status (Mensah et al., 2017). Installed electricity generation capacity increased by 39.3 percent from 3,795 MW in 2016 to 5,288 MW in 2020. The cumulative installed capacity for power generation during the period spanning 2016 to 2020 was derived from a diverse array of operational power plants, encompassing hydroelectric, thermal-based, and additional renewable energy facilities. This aggregate capacity stems from the combined contributions of these various power plant types (Energy Commission-Ghana, 2021).

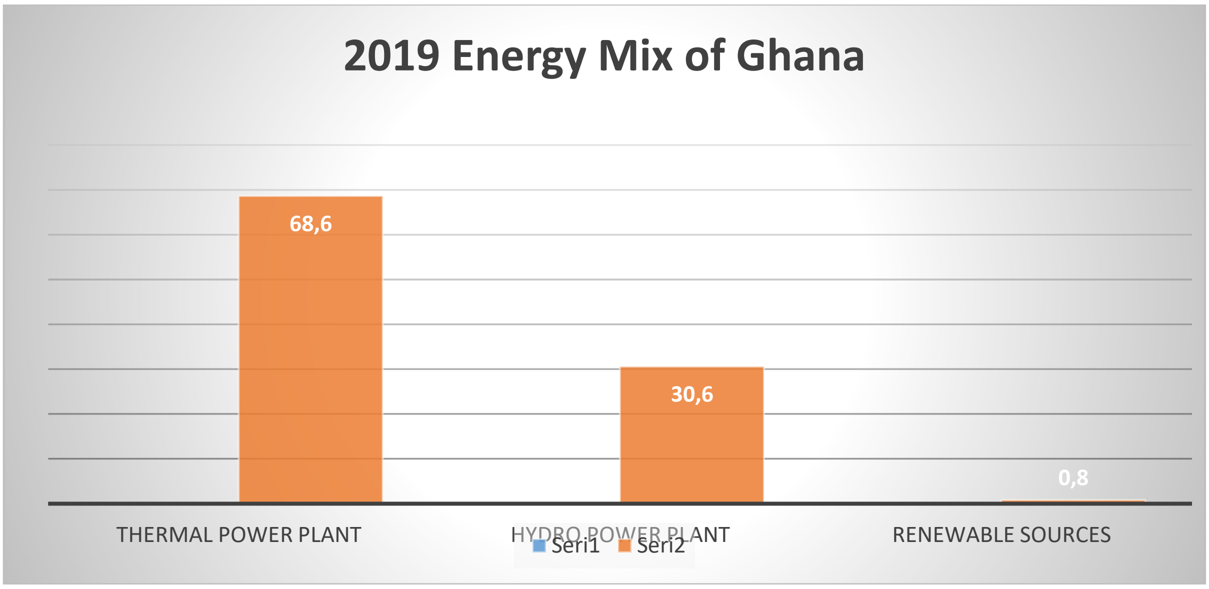

Figure 2.2. 2019 Contribution of installed generation capacity in percentages

(Source: Generated based on data from Energy Commission of Ghana, 2020)

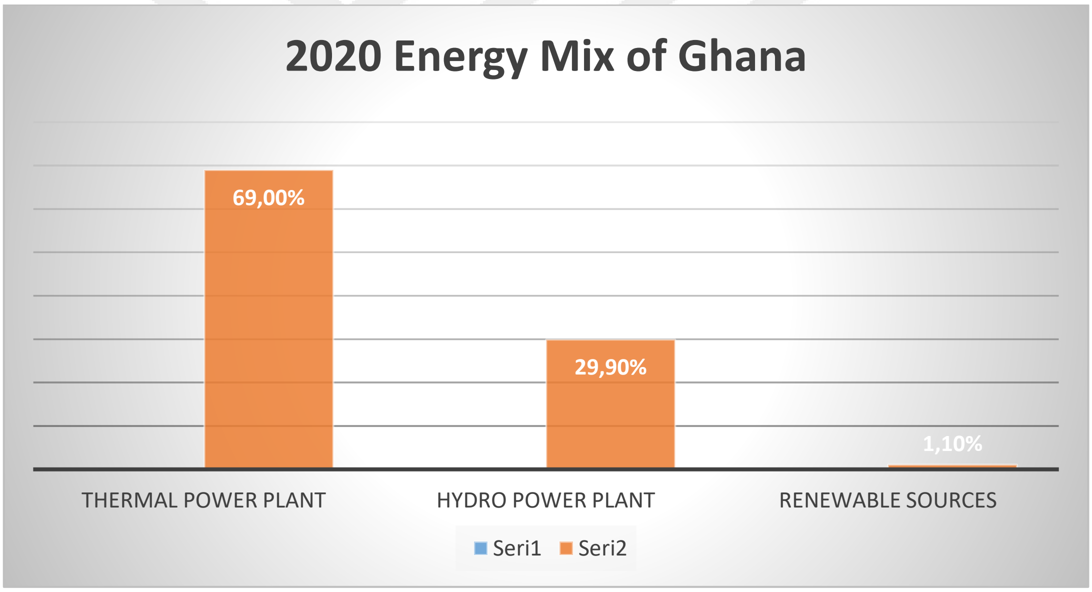

Figure 2.3. 2020 Contribution of installed generation capacity in percentages

(Source: Generated based on data from Energy Commission of Ghana, 2021)

Throughout the year 2020, the composition of the energy portfolio demonstrated a notable degree of constancy, with hydroelectric power constituting approximately 29.9 percent of the comprehensive installed capacity. Conventional thermal power plants emerged as a substantial contributor, accounting for 69.0 percent of the total installed capacity for the same period, whereas renewable energy sources contributed 1.1 percent. Commencing from the year 2015, there has been a discernible shift in the prominence of power generation sources, as thermal energy has progressively surpassed hydroelectricity to establish itself as the preeminent source of electricity generation within the Ghanaian context (Energy Commission-Ghana, 2021).

2.5. Sources of Domestic Energy in Developing Nations

The majority of Sub-Saharan Africa's (SSA) rural energy demands are met by fuelwood and charcoal. Given the high consumption rates, the long-term supply of fuelwood is in jeopardy (Wessels et al., 2013). The magnitude of Africa's savannas' declining fuelwood supplies emphasizes how crucial it is to provide affordable energy for rural economic growth (Wessels et al., 2013). In SSA, biomass is used as the main residential energy source by more than 80% of households, primarily for cooking and heating (Scholes and Biggs 2004). Most rural communities in sub-Saharan Africa are underdeveloped, which forces them to rely heavily on wood or animal dung as a source of energy for lighting, heating, and cooking. Thus, the bulk of the poor in both rural and urban regions remove enormous swaths of land from its woody vegetation to meet their household energy demands, with disastrous ecological effects (Masekoameng et al., 2005). The natural environment of sub-Saharan Africa is getting more fragile and is being progressively threatened by deforestation and severe soil erosion as a result of the continent losing a net total of about five million hectares of tropical forest every year (Awino 1999). Uganda, classified as a developing country, sustains a populace of 47.12 million individuals as of the year 2021. Notably, the distribution of this population delineates 87% residing in rural environs and the remaining 13% dwelling within urban precincts (Sebbit et al., 2004).

Like the prevailing energy consumption patterns in a significant portion of less-developed countries, this nation is heavily reliant on biomass as its predominant energy reservoir. The residential sector takes the lead in the nation's total energy consumption, constituting an imposing 81%. In a substantial number of households across the nation, biomass takes center stage as the primary source of energy for domestic applications (Sebbit et al., 2004). In Uganda, rural communities typically use fuelwood, but urban households prefer charcoal. In some regions, the rate at which fuelwood is used surpasses the rate at which naturally occurring woody vegetation is created, placing pressure on the natural vegetation, and contributing to soil erosion and water body silting. Major environmental issues, such as widespread deforestation and the loss of biodiversity, can be anticipated to arise soon if future fuelwood consumption is equal to the pace of population expansion in this growing country (Knopfele, M. 2004).

2.6. Domestic Energy Sources in Ghana

Ghana possesses a profusion of energy resources, encompassing biomass, hydroelectric power, solar energy, wind energy, oil, and natural gas. Among these, biomass energy stands as the prevailing energy type, constituting a significant proportion of approximately 64% of Ghana's aggregate primary energy provision. Wood fuel and charcoal are the primary sources of biomass energy (Duku et al., 2011). In Ghana, the three traditional energy sources are wood, charcoal, and dung. Wood is the most regularly utilized cooking and heating fuel, whereas charcoal is generally used for commercial purposes. In some rural places, dung is used as a fuel source. Dung is a renewable resource that is often overlooked as a potential fuel source. It is abundant in rural areas where livestock are kept. When burned, dung produces little smoke and can be a cheaper alternative to wood or charcoal.

Ghana has a high rate of deforestation, which has made wood increasingly scarce and expensive. As a result, many individuals have turned to charcoal as their major source of fuel. This has, however, contributed to air pollution and health issues such as respiratory ailments (Ackah & Asomani, 2015). As outlined by Paudel et al. in 2021, the increased uptake of environmentally sound alternatives for cooking energy assumes a pivotal role in the realization of the Sustainable Development Goal—SDG13—along with its interconnected developmental aspirations. This transition becomes especially crucial in enhancing the socio-economic well-being of marginalized populations, particularly women and children, residing within economically disadvantaged nations. The accessibility to clean and contemporary energy sources, including liquefied petroleum gas (LPG), electricity, and renewable energy forms, remains constrained within many developing countries. This limitation can be attributed to a multitude of factors encompassing supply limitations, concerns pertaining to affordability, and individual preferences, among other influential variables (Paudel et al., 2021).

2.7. Ghana's Energy policy

The National Energy Policy of 2010 outlines a comprehensive framework devised to tackle the persistent challenge of escalating energy demands within the nation. This policy delineates robust strategies encompassing waste-to-energy management, the deployment of renewable energy sources, and the enhancement of overall energy efficiency. These measures underscore the imperative for active involvement of the private sector, the refinement of policy infrastructure, and the facilitation of efficient and sustainable energy generation practices. A pivotal directive emphasized within the National Energy Policy pertains to the optimal harnessing of the country's extensive hydropower potential, necessitating proactive engagement by the governmental apparatus (Government Document, 17 June 2023).

The Republic of Ghana is resolutely committed to the adoption of renewable energy as a means of ensuring universally accessible, economically viable, and environmentally sustainable electricity provision. As an embodiment of this commitment, Ghana has outlined a target of integrating 10% renewable energy sources within its broader energy portfolio by the year 2020 (SEforAll, 23 August 2022). To realize this objective, the government has implemented an array of strategic policies and incentives, notably including the Renewable Energy Act of 2011 (Act 832). This legislation establishes a robust legal and institutional framework conducive to fostering renewable energy development within the Ghanaian context. Supplementary policy initiatives comprise the formulation of a National Renewable Energy Action Plan (NREAP), the establishment of a Renewable Energy Fund (REF) aimed at supporting small-scale initiatives, and the initiation of a Green Climate Fund endeavor to stimulate private sector investments in renewable energy ventures (IEA, 16 June 2023). However, an assessment of progress at the conclusion of 2017 unveiled that only a mere 0.5% of the envisaged target for the integration of renewable energy sources into the national energy supply had been realized (SS, 23 August 2022).

In the year 2019, the government of Ghana unveiled its strategic blueprint, announcing intentions to elevate this percentage to 30% by the culmination of 2030. This steadfast commitment to renewable energy constitutes a fragment of Ghana's overarching aspiration to achieve comprehensive accessibility to electricity for all by the year 2025. This entails a deliberate endeavor to amplify the contribution of renewable energy sources within the national energy framework, elevating it from the modest threshold of 42.5 megawatts registered in 2015 to a more substantial capacity of 1363.63 megawatts, as stipulated within the Ghana Renewable Energy Master Plan of 2019. A sphere wherein Ghana has exhibited significant advancement pertains to its energy policy landscape.

A notable milestone transpired in 2010 when the government launched the "National Energy Policy." This strategic blueprint outlines multifaceted objectives encompassing the augmentation of energy access, the enhancement of energy utilization efficiency, and the widespread adoption of renewable energy resources (National Energy Policy, 2010). Embedded within the government's agenda for renewable energy is the dual aspiration of elevating the proportion of renewable energy sources within the overall national energy composite, while concurrently ensuring a streamlined process of both production and utilization (Obeng-Darko, 2018).

These communities hold notable significance for two primary rationales. In the initial instance, they serve as instrumental mechanisms in diminishing Ghana's reliance on fossil fuels, a prominent contributor to the emission of greenhouse gases. Secondly, these commitments empower Ghana to diversify its energy composition, consequently enhancing its energy security and concurrently facilitating the attainment of universal energy accessibility. A particularly noteworthy attribute of wind and solar energy is their minimal water requisites for operational efficiency. This intrinsic quality renders them environmentally benign, exempt from contributing to water resource contamination or overuse, thereby avoiding competition with critical domains such as agriculture and potable water supplies. By accounting for these multifaceted factors, Ghana is poised to make substantial strides in ameliorating its environmental landscape (Arthur, 2022).

The trajectory of Ghana's progress is intrinsically intertwined with the formulation and execution of its energy policy. The nation possesses ample renewable energy reservoirs that hold the potential to comprehensively cater to its energy demands. However, to unlock the complete potential of Ghana's renewable energy endowment, a series of impediments necessitate resolution. These challenges encompass multifarious facets, including the financial viability of technologies, funding-related complexities, scientific and technical barriers, institutional and regulatory limitations, and the indispensable requisites for establishing a reliable and sustainable energy production framework. Finally, energy storage and load matching must be a major part of Ghana's energy strategy because they are crucial to the efficient and dependable production of energy from renewable sources (Kuamoah, 2020b).

2.8. The Profile of Ghana’s Energy Market

The National Energy Policy of 2010 encompasses a strategic framework designed to tackle the persistent challenge of escalating energy demands within the nation. This policy framework accentuates the imperative of effectively addressing the mounting energy requisites through a multifaceted approach. Key focal points include the management of waste-to-energy mechanisms, the widespread adoption of renewable energy sources, and the enhancement of overall energy utilization efficiency. These directives collectively underscore the essentiality of active involvement from the private sector, the refinement of policy infrastructure, and the facilitation of efficient and enduring energy generation practices. A prominent directive articulated within the National Energy Policy pertains to the effective harnessing of the extensive potential offered by small-scale hydroelectric installations, an initiative that is envisioned to be executed by the governmental apparatus (National Energy Policy, 2010).

The governance of Ghana's energy sector is vested within the purview of the Ministry of Energy. This governing body holds the responsibility of conceiving and enacting policies aimed at safeguarding the sustainable progression of the nation's energy assets over the extended term. Furthermore, the Electricity Regulatory Commission, entrusted with the mandate of fostering an environment of competition, operational efficacy, and high standards within the electricity domain, assumes a regulatory role over this sector (EP, 25 August 2022). Ghana's energy landscape has undergone advancements, encompassing a diversified range of energy sources, comprising both conventional and sustainable options. Notably, oil emerges as the predominant energy resource, constituting an approximate 60% share of the nation's comprehensive energy consumption.

Additional substantial contributors within this energy matrix encompass coal, contributing to approximately 24%, followed by hydropower at 10%, and natural gas with a share of 5% (Energy Commission of Ghana, 2021). Ghana has formulated an ambition to augment the proportion of renewable energy sources within its comprehensive energy amalgamation by the year 2030. This commitment to reshaping its energy composition is underscored by the nation's updated Nationally Determined Contribution (NDC) presented to the United Nations in November 2021, in alignment with its commitment to the Paris Agreement. As part of this endeavor, Ghana aspires to effectuate a substantial reduction of its cumulative greenhouse gas (GHG) emissions, targeting a decline of approximately 64 million metric tons of CO_2 equivalent by the designated year of 2030 (Government Document, 17 June 2023).

Ghana boasts noteworthy reserves of oil and gas, albeit a substantial proportion of its oil extraction activities are derived from offshore fields. The nation's resource endowment also encompasses significant deposits of coal and uranium. Regrettably, limited investment and inadequate infrastructure have impeded the extensive exploitation of these valuable reserves, leading to their minimal utilization. Ghana's renewable energy portfolio encompasses solar, wind, biomass, and geothermal resources, all of which exhibit considerable untapped potential. Presently, their realization remains constrained due to insufficient investment and awareness. Nonetheless, this sector holds substantial promise for significant expansion in the impending years, as highlighted in relevant evidence (Evidence-from-Ghana-Oil-Discovery, n.d.). In a notable policy stride, the government introduced the Renewable Energy Master Plan (REMP), a substantial $5.6 billion initiative unveiled in 2019. The execution of this plan spans a span of 12 years, from 2019 to 2030.

Its primary impetus lies in stimulating economic advancement, augmenting societal well-being, and ameliorating the repercussions of climate change. The central agenda pertains to the development and promotion of Ghana's copious renewable energy resources. Presently, Ghana's energy matrix comprises a blend of renewable (10%) and non-renewable (90%) energy sources, with biomass (46.667%) and oil (40.52%) occupying the predominant share. Natural gas (10%) and hydroelectric power (7%) constitute the ensuing contributions. Analyzing energy consumption patterns spanning from 2000 to 2020, the aggregated sectoral consumption equated to 130632 kilotonnes of oil equivalent (ktoe). This distribution was as follows: the residential sector accounted for 62,736 ktoe (48%) of the overall total, while industrial (18254 ktoe), service (5033 ktoe), agricultural (1957 ktoe), and transportation (42652 ktoe) sectors collectively contributed to the remainder (Takase et al., 2022).

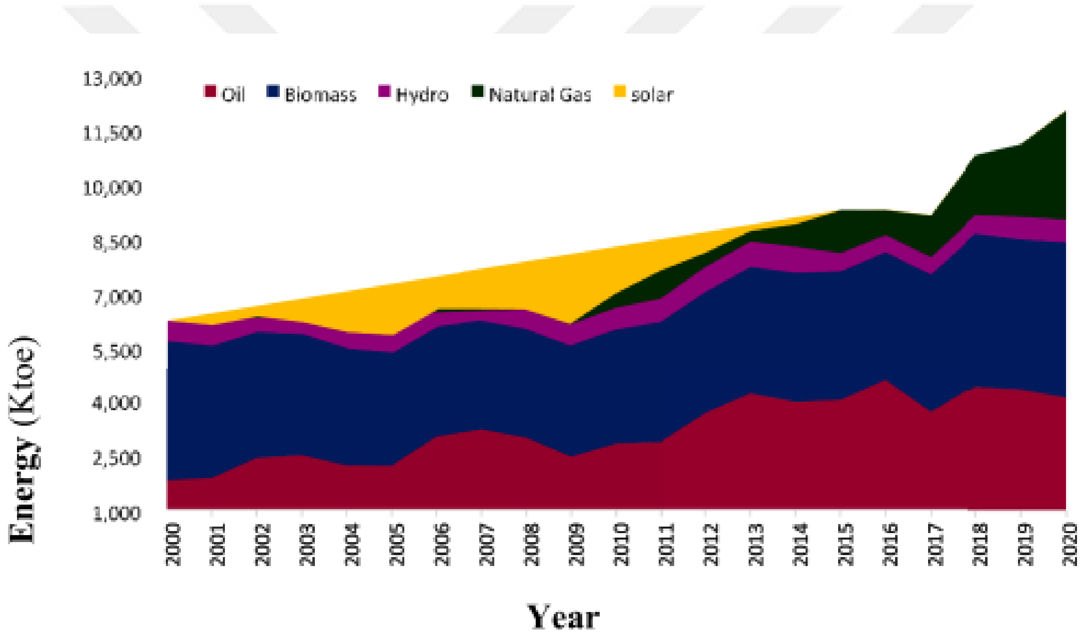

Figure 2.4. Total Amount of Energy Circulation

(Source: National Energy Statistics of Ghana (2020))

2.9. Energy Security and Sustainable Future of Ghana

Ghana is aiming to secure future sustainability and energy security. Although there is a lot of hydroelectric potential in the nation, very little of it has been used. Due to Ghana's reliance on imported oil and gas, the country has experienced an upsurge in power disruptions in recent years. As a result, Ghana is making an effort to diversify its energy sources and use more renewable energy sources (Gyamfi et al., 2015). Not only Ghana but other nations also experience energy instability. Power outages are frequent and energy availability is scarce in many parts of Africa. Businesses, medical facilities, educational institutions, and other vital services are all impacted by this unreliable electrical supply. Additionally, it inhibits economic expansion and reduces chances for advancement. Ghana is working to address these issues by investing in renewable energy sources and increasing access to electricity (Kumi, 2017). In Ghana, energy security is a growing concern.

The country has experienced several power outages in recent years, and its reliance on imported oil makes it vulnerable to disruptions in the global market (Gyamfi et al., 2015). Ghana’s energy sector is dominated by thermal power, which accounted for about 70% of total electricity generation in 2015. Many of these plants are fueled by natural gas, with some heavy fuel oil and light fuel oil also used. Ghana imports all of its natural gas and most of its oil, making the country vulnerable to supply disruptions (Energy Commission-Ghana, 2021). In 2015, Ghana’s installed capacity was about 2,190 MW. However, actual generation was only about 1,690 MW due to a number of factors, including inadequate maintenance, fuel shortages, and transmission constraints. These problems have led to frequent power outages across the country (Energy Commission-Ghana, 2021)

2.9.1. Energy Security Improvement Initiatives

The Ghanaian government has made a few efforts in recent years to increase energy security. These initiatives encompass the enhancement of energy efficiency measures, coupled with targeted investments in renewable energy avenues, notably encompassing solar, biomass, and wind energy. In a strategic endeavor to mitigate Ghana's dependency on imported fossil fuels, the government has embarked upon a series of concerted endeavors, as underscored by the establishment of various projects (Kuamoah, 2020b). The "Master Plan for Gas Utilization in Ghana" by the Ghana National Gas Company (GNGC) is one such endeavor. This strategy intends to boost the nation's usage of natural gas for both electricity generation and as a fuel for vehicles. Additionally, the GNGC is trying to create new infrastructure to facilitate the expansion of Ghana's natural gas industry (Gas Master Plan, 2016). Another key initiative is the "Ghana Electricity Expansion Project," which includes plans to expand electricity access across the country.

The project also involves the expansion of electricity infrastructure, including the construction of a new transmission line. Ghana invites investors, both national and international, to participate in its energy sector. Ghana has firmly established a regulatory framework to govern its natural gas sector, exemplified by enactments such as the Ghana National Gas Company Act of 2004. An ongoing project, bolstered by support from the African

Development Bank, seeks to elevate electricity accessibility from 30 percent to 60 percent within urban locales and from 12 percent to 50 percent within rural regions, as articulated in the Electricity Supply Plan for Ghana (2021).

One pivotal stride involves the formulation of a National Energy Policy, a strategic instrument delineating a comprehensive long-term vision for the nation's energy domain. This policy blueprint concurrently delineates stratagems aimed at enhancing energy security. Ghana's energy sector has been undergoing a notable paradigm shift, geared toward rendering it more enticing for private investments. These multifaceted reforms encompass the institutionalization of an Independent Power Producer (IPP) office under the aegis of the Ministry of Energy, in tandem with the inauguration of a dedicated Renewable Energy Fund. Of noteworthy pertinence is the Ghana Renewable Energy Fund (GREF), a distinct initiative within the Ghanaian landscape. This financial mechanism channels resources into renewable energy ventures, aspiring to amplify the proportion of renewables within the national energy composite. This concerted endeavor holds the potential to curtail Ghana's reliance on imported fossil fuels, thereby fostering enhanced energy security. Concurrently, the governmental apparatus has orchestrated the establishment of an Energy Commission, tasked with overseeing the energy sector's trajectory and formulating policies conducive to its efficacious and sustainable advancement. In conclusion, energy security is a top priority for Ghana as the country looks to ensure a sustainable future. Achieving energy security will require a concerted effort from all sectors of society and the government. Ghana has the potential to become a leader in renewable energy in Africa, but only if the right policies and investments are put in place. With the right steps, Ghana can achieve energy security and create a more sustainable future for all its citizens.

2.10. Public-Private Partnership (PPP) in the Energy Sector

The energy sector emerges as a paramount driver of Ghana's economic fabric, wielding substantial influence. This domain stands as a robust generator of employment opportunities, engaging a significant workforce and concurrently infusing government coffers with revenue streams. A pivotal facet of enhancing the energy landscape involves a pronounced pivot toward fostering private-public partnerships (PPPs), as underscored by Awuku et al. (2022a). These collaborative frameworks empower private enterprises to assume pivotal roles in both financing and orchestrating energy ventures. Consequently, this dynamic configuration expedites project realization while concurrently alleviating the fiscal burdens borne by the governmental apparatus. A concrete illustration within Ghana's energy panorama resides in the collaboration forged between the government and Sino hydro, a Chinese construction enterprise, exemplifying the PPP paradigm's tangible manifestation (World Tribune, 7 November 2022).

Public-private partnerships (PPPs) have emerged as instrumental catalysts propelling the expansion of Ghana's energy sector. These collaborative endeavors have been strategically harnessed to cultivate a conducive milieu that incentivizes private sector investments within the nation's energy domain. Insights gleaned from World Bank data unveil a substantial maturation within Ghana's energy landscape over the preceding decade. For instance, the recorded surge in power plant installed capacity from 1,540 MW to 4,922 MW in 2019 stands as a demonstrative testament to this dynamic evolution. This commendable upswing is underpinned by substantial investments effectuated within the energy sphere, courtesy of PPPs, executed in concert by the Ghanaian government and private stakeholders, as posited by Senanu et al. (2022). Following the establishment of the Akosombo dam, Ghana's electricity generation underwent a notable paradigm shift. The trajectory traversed from a landscape marked by diesel generators and self-contained electricity delivery systems primarily owned by industrial mining enterprises and factories, subsequently transitioning into a hydrological phase.

Presently, the energy matrix resides within a thermal complement, propelled by the deployment of gas and/or light crude oil. However, the energy landscape has been marred by recurrent episodes of power shortages, ushering this issue into the sphere of recurring developmental concern. The resultant implications encompass stymied industrial operations, constricted employment opportunities, compromised income streams, and a perturbed societal fabric (Amoako-Tuffour, 2016). The Energy Sector Reform Program's (ESRP) immediate goal is to provide a transparent and thorough roadmap of strategic actions, reforms, and policies that would increase the sector's efficiency, ensure sustainability, and meet the demand for power. Ghana's PPP power goals include expanding the tax base, raising compliance and transparency, reducing fraud, and enhancing Ghana's business climate competitiveness. A dependable and sustainable supply of electricity is crucial to produce goods, services, and overall economic infrastructure. Exploring alternative energy mixes and fostering private sector participation offer opportunities on both the supply and demand fronts in this context (Senanu et al., 2022).

The inception of Ghana's Energy Sector Recovery Program (ESRP) in 2018 marked a strategic initiative geared towards resolving prevailing challenges within the energy sector and ensuring the provision of enduring and accessible energy resources for the entire citizenry. To effectively achieve its set objectives, the program has strategically accorded precedence to projects founded on the framework of public-private partnerships (PPPs). These projects are strategically channeled across domains encompassing renewable energy, energy efficiency, as well as transmission and distribution infrastructure (Electricity Company of Ghana, 16 June 2023).

Significant private investment has been attracted to Ghana's PPP initiatives in the energy sector, with a number of international and local businesses collaborating with the government to develop and run energy projects. For instance, Ghana and Siemens AG signed a $2.6 billion deal in 2019 to upgrade Ghana's power grid and increase its dependability and energy efficiency. The partnership is also anticipated to transfer technology to Ghana and create jobs (Muhammad-Sukki et al., 2022). The Public Procurement Act, 2003 (Act 663) is a key component of Ghana's legal and regulatory framework for PPPs in the energy sector. This Act establishes rules for public entities' purchases of goods, labor, and services as well as best practices. The success of PPPs depends on the public procurement process being transparent, competitive, efficient, and economical (CL, 16 June 2023). In addition, the Energy Commission was established by the Energy Commission Act, 1997 (Act 541), which is in charge of overseeing the industry. In accordance with the Act, the commission is tasked with promoting energy efficiency, ensuring energy security, and fostering competition in the industry. The Energy Commission oversees issuing licenses, permits, and regulations and making sure that technical, environmental, and safety standards are followed (FAO, 16 June 2023).

The legal and regulatory system continues to have flaws, though. Aiming to promote and regulate PPPs, the Public-Private Partnership Act, 2012 (Act 921) lacks specific provisions or guidelines for PPPs in the energy sector. Due to this ambiguity, project implementation may be delayed, and investors may become uneasy (UNECA, 16 June 2023). The effective management of public-private partnerships (PPPs) within the energy sector necessitates the establishment of distinct and comprehensive regulations tailored to the unique dynamics of this context. This regulatory framework should delineate the roles and responsibilities of all involved stakeholders, ensuring transparency, equity, and accountability throughout the procurement process. Furthermore, these guidelines should actively promote the integration of alternative energy sources and introduce fiscal incentives to incentivize private investment (Ministry of Finance and Economic Planning [MOFEP], 2011). The operationalization of the PPP model within Ghana's energy landscape has encountered impediments arising from inadequacies in accountability and transparency. While envisioned as a conduit to infuse private capital and expertise, the PPP framework has yielded unintended outcomes, manifesting as escalated costs juxtaposed with limited enhancements in service performance (Awuku et al., 2022).

CHAPTER THREE

RELATIONSHIP BETWEEN ENERGY USE AND THE ECONOMY

3.1. Energy Indicators

A pivotal element of sustainable development is the provision of sufficient and reliable energy services at an equitable cost, adhering to safety and environmental standards, and aligning with the socio-economic developmental needs. Energy plays a fundamental role in poverty alleviation, the enhancement of human well-being, and the elevation of living standards (UNDP, et al. 2000). Nonetheless, most prevailing energy supply and consumption patterns are deemed unsustainable (UN, 2001). The absence of dependable and secure energy sources, thus, impairs the prospects of economic growth in numerous regions. Moreover, energy-related environmental degradation poses a hindrance to sustainable development in certain areas. The progression from subsistence agricultural economies to contemporary industrial and service-oriented societies has been heavily reliant on the availability of dependable and cost-effective energy services. The provision of energy is indispensable for the advancement of social and economic well-being, playing a pivotal role in fostering industrial and commercial prosperity. The overarching goal is to establish a flourishing society, characterized by robust health, environmental cleanliness, and a sustainable economy.

During the ninth session of the Commission on Sustainable Development (CSD-9) in 2001, significant attention was given to energy-related issues. Subsequently, the international community underscored the criticality of energy access in achieving the Millennium Development Goal of reducing poverty by half by 2015, as declared during the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa, in 2002 (UN, 2000). In the pursuit of more comprehensive national policies for sustainable development, the WSSD aimed to enhance accessibility to reliable and cost-effective energy services for impoverished communities. Furthermore, the summit called for a shift away from unsustainable energy production and consumption patterns. Therefore, it is imperative that policymakers possess a comprehensive understanding of the implications and ramifications associated with diverse energy initiatives, as well as alternative strategies, methodologies, and schemes, concerning the advancement of national development and the viability of long-term sustainability within their respective countries. Once indicators are meticulously assessed and comprehended, they can serve as valuable instruments for disseminating information regarding energy and sustainable development concerns to both the public and decision-makers, while also fostering productive discourse among various institutional stakeholders. In response to decisions made by the United Nations Commission on Sustainable Development (CSD) and Chapter 40 of Agenda 21, the United Nations Department of Economic and Social Affairs (UNDESA) undertook the task of formulating a comprehensive set of Indicators for Sustainable Development (ISD) in 1995. This initiative resulted in the compilation of a total of 58 Indicators for Sustainable Development. However, it is noteworthy that only three of these indicators pertained to energy-related aspects, specifically annual energy consumption per capita, intensity of energy use, and the proportion of renewable energy resources in the overall consumption (UNDESA, 2001).

The importance of indicators to aid countries in making well-informed decisions pertaining to sustainable development was duly recognized during the 1992 Earth Summit. This recognition is explicitly articulated in Chapter 40 of Agenda 21, which encourages national governments and various international entities, be they governmental or non-governmental, to establish their respective sets of sustainable development indicators (Kolbasov, 1992). Considering the growing global attention on energy matters and its critical role in actualizing the World Summit Sustainable Development Agreement at the national level, numerous regional and international organizations have actively collaborated to devise indicator frameworks. These frameworks are intended to assist nations, especially those in the developing world, in evaluating their advancements in energy and sustainable development at the national level (WSSD, 2002).

The economic dimension of energy indicators encompasses two key themes: use and production patterns, and security of supply. Under the theme of use and production patterns, various sub-themes are addressed, including overall use and productivity, supply efficiency, production, end-use, fuel mix, and prices. Additionally, the security theme includes factors like dependency on imports and strategic fuel stocks. Two significant aggregated indicators are utilized to explore overall use and productivity: energy use per capita and energy use per unit of GDP. The provided text discusses several indicators that offer valuable insights into the combined energy intensity of a society and its economy. These indicators play a critical role in assessing the sustainability of consumption patterns. However, it is imperative to exercise prudence while interpreting these indicators, as they are influenced not only by energy intensities within various economic sectors and activities but also by external factors such as climatic conditions, geographical location, and the overall economic structure. Furthermore, the text highlights the significance of an indicator related to supply efficiency, which pertains to the efficiency of energy conversion and distribution. This indicator serves as a useful tool for monitoring energy efficiency in transformation processes like power stations and refineries. Additionally, there is a reference to the research by Vera et al. in 2001, which is likely to provide further in-depth insights into the subject matter.

The energy-related metrics within the environmental domain focus on assessing the impacts of energy usage on the atmosphere, water bodies, and terrestrial ecosystems. When evaluating the airspace, pollutants that worsen air quality and greenhouse gas emissions linked to the effects of climate change are considered. The topic of water specifically addresses how contaminant discharges affect water quality. The land theme specifically addresses deforestation, waste production and disposal, as well as soil quality. The prevailing worldwide pattern of increasing emissions of greenhouse gases stands as a substantial subject of environmental apprehension, carrying the potential to induce enduring climatic ramifications for the planet (International Energy Agency (IEA), 2007).

As pointed out by Serwaa et al. in (2015), the provision of contemporary energy services for developmental purposes constitutes a complex undertaking, necessitating meticulous strategizing grounded in dependable data. Indicators assessing energy accessibility serve as tools for quantifying and monitoring advancements in endeavors aimed at broadening energy availability. These indicators furnish essential insights for remedial measures and the replication of successful initiatives. In contrast to its sub-Saharan counterparts, Ghana has made commendable strides in extending access to modern energy services; however, there remains a call for further endeavors to align with the aspiration of achieving universal electricity access goals. (Serwaa et al., 2015). Ghana has emerged as a participant among the countries that have devised a SE4All (Sustainable Energy for All) country action plan, under the auspices of collaborative support extended by the United Nations Development Programme (UNDP). The primary thrust of this strategic framework revolves around enhancing the provision of contemporary energy services aimed at facilitating productive applications. Notably, it is important to underscore that the Government of Ghana had already established a commitment towards attaining a 50% accessibility target for LPG (liquefied petroleum gas) by the year 2015, antedating the advent of the SE4All Initiative.

Table 3.1. Energy Indicators (2010-2019)

Energy Indicator	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total primary energy supply	Ktoe	6,947	7,610	8,363	8,565	9,148	9,551	9,520	9,622	10,852	11,159
Total Final Energy Consumed	Ktoe	5,629	6,174	6,613	6,887	6,983	7,170	6,649	7,065	7,643	7,974
Total Electricity Generated	Gwh	10,166	11,200	12,024	12,870	12,963	11,491	13,023	12,067	16,246	18,188
Total Electricity Consumed	Gwh	8,317	9,187	9,258	10,583	10,695	9,780	11,518	12,246	13,185	13,943
Total Petroleum Products Consumed	Ktoe	2,491	2,827	3,318	3,422	3,377	3,545	3,274	3,155	3,483	3,794
Total Biomass Consumed	Ktoe	2,464	2,576	2,589	2,676	2,792	2,785	2,783	2,829	2,961	2,961
Population	Million	24.7	25.3	25.9	26.5	27.0	27.7	28.3	29.0	29.6	30.2
GDP current	Million USD	32,186	39,517	41,656	64,401	52,950	47,767	54,858	58,920	65,556	66,984
Total Energy Consumed per capita	toe/capita	0.23	0.24	0.26	0.26	0.26	0.26	0.23	0.24	0.26	0.26
Total Electricity Generated/capita	Kwh/capita	411.6	442.7	464.2	485.7	480.1	414.8	460.2	485.8	548.6	602.3
Total Electricity Consumed/capita	Kwh/capita	336.7	363.1	357.4	399.4	396.1	353.1	407.0	422.8	445.2	461.7
Total Petroleum Products Consumed/capita	toe/capita	0.10	0.11	0.13	0.13	0.13	0.13	0.12	0.11	0.12	0.13
Total Biomass Consumed/capita	toe/capita	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total Electricity Consumed/GDP	kWh/US$ 1,000 of GDP	258.4	232.5	222.2	164.3	202.0	204.8	210.0	207.8	201.1	208.2
Total Primary Energy Supply/GDP	toe/US$ 1,000 of GDP	215.8	192.6	200.8	133.0	172.8	199.9	173.5	163.3	165.5	166.6
Total Primary Energy Supply/capita	toe/capita	0.28	0.30	0.32	0.32	0.34	0.34	0.34	0.33	0.37	0.37

(Source: Energy Commission of Ghana, National Energy Statistics 2000-2019)

The data presented in the above table elucidates a growth trajectory in Ghana's population, ascending from nearly 25 million individuals in 2010 to approximately 32 million in 2019. Concurrently, employing a consistent framework of 2010 prices, the Gross Domestic Product (GDP) demonstrated an escalation from around 32 million United States Dollars (USD) in 2010 to about 67 million USD in 2019. Statistical analysis reveals a correlation coefficient denoted as $r(8) = 0.98$, with a significance level of $p < 0.05$, indicating a robust and statistically significant positive correlation between the ascending population figures and the augmenting Gross Domestic Product. This underscores a substantive interrelationship between the two indicators. The cumulative energy output experienced growth from 10,166 gigawatt-hours (GWh) in 2010 to 18,188 GWh in 2019. Concurrently, the aggregate final energy consumption, representative of energy not utilized for conversion into alternative energy forms, underwent an increase from 5,269 kilotonne oil equivalent (ktoe) to 7,974 ktoe over a span of a decade.

In a similar timeframe, the overall electricity consumption, encompassing commercial losses, advanced from 8,317 GWh in 2010 to 13,943 GWh in 2019. Conversely, the total biomass consumption displayed negligible alterations between 2006 (2,464 ktoe) and 2012 (2,961 ktoe). The aggregate consumption of petroleum products exhibited a rise, ascending from 2,491 kilotonne oil equivalent (ktoe) in 2010 to 3,794 ktoe in 2019. Simultaneously, the overall final energy consumption per individual, denoted as per capita, demonstrated an increase from 0.23 tonnes of oil equivalent (TOE) per capita in 2010 to 0.26 TOE per capita in 2019. Notably, the per capita measures for electricity generation and consumption both witnessed upward trends over this period. Specifically, the electricity generated per individual rose from 411.6 kilowatt-hours (KWh) per capita in 2010 to 602.3 kWh per capita in 2019, while the electricity consumed per capita increased from 336.7 kWh per capita in 2010 to 461.7 kWh per capita in 2019.

Conversely, the per capita consumption of Total Biomass remained constant at 0.10 tonnes of oil equivalent (TOE) per capita over the decade spanning from 2010 to 2019. In contrast, the per capita consumption of Total Petroleum Products experienced an increase from 0.10 TOE per capita to 0.13 TOE per capita by the year 2019. Additionally, the cumulative Primary Energy Supply underwent augmentation from 6,947 kilotonne oil equivalent (Ktoe) in 2010 to 11,159 Ktoe in 2019. Consequently, this phenomenon precipitated an escalation in the per capita Primary Energy Supply, surging from 0.28 tonnes of oil equivalent (TOE) per capita in the year 2010 to 0.37 TOE per capita by the year 2019. However, a converse trend was evident in terms of energy consumption linked to economic parameters. Specifically, there was a decrement observed in the relationship between Total Electricity Consumed and Gross

Domestic Product (GDP), declining from 258.4 kilowatt-hours (KWh) per USD 1,000 GDP in 2010 to 208.2 KWh per USD 1,000 GDP in 2019. Similarly, the proportion of Total Primary Energy Supply to GDP exhibited a decline, contracting from 215.8 TOE per USD 1,000 GDP in 2010 to 166.6 TOE per USD 1,000 GDP in the year 2019.

3.2. Energy Consumption Patterns

Residential electricity consumption accounts for over 50% of total electricity generation in Ghana (Yiran et al., 2020). The residential sector in Ghana consumes roughly 40% of the total electricity used, with urban areas contributing a significant 70% of this portion (Sakah et al., 2019). Moreover, within Ghana, residential activities account for about 47% of the overall energy consumed (IO, 26 May 2023). The demand for residential electricity has shown a remarkable increase, growing by an average of 6.2% annually between 2000 and 2010, and experiencing a sharp 15.4% surge in 2013 alone (ESS, 26 May 2023). This heightened demand is primarily propelled by the rapid expansion of major cities like Accra, Tema, Takoradi, and Kumasi, which has led to greater electricity needs for residential areas (ESS, 26 May 2023). Several elements have contributed to the upsurge in residential energy consumption within Ghana. A pivotal factor resides in the swift expansion of major urban centers, notably Accra, Tema, Takoradi, and Kumasi, which has substantively propelled the demand for residential electricity (Sakah et al., 2019). Furthermore, heightened ownership of household appliances serves as another catalyst for augmented residential energy consumption in the country. Evidenced by a study conducted in urban Ghanaian households, the possession of appliances emerges as a significant determinant influencing electricity consumption within the residential domain (Sakah et al., 2019). It is essential to acknowledge the role of energy efficiency considerations as well in the context of residential energy usage. As underscored, the residential sector in Ghana contributes to 47% of the overall final energy utilization (IO, 26 May 2023). Addressing inefficiencies in energy usage within this residential sector could feasibly represent an efficacious avenue toward curtailing energy consumption.

Renewable energy constitutes another noteworthy facet within the context of residential energy consumption. The principal sources of renewable energy in Ghana comprise biofuels and waste, predominantly harnessed within the residential sector (MPRA, 26 May 2023). The augmentation in residential energy consumption in Ghana can be chiefly attributed to urbanization and the possession of household appliances. Yet, the amelioration of energy efficiency and the adoption of renewable energy sources hold the potential to mitigate this heightened consumption. This section deliberates on the challenges confronted by Ghana in the pursuit of energy efficiency and sustainability in the residential domain. First, a lack of awareness persists, as a substantial number of Ghanaian households remain uninformed about the advantages of energy efficiency and sustainability, leading to their limited prioritization (Diawuo et al., 2018). Financing emerges as a major hurdle for households aspiring to invest in energy-efficient appliances or renewable energy systems (Diawuo et al., 2018). Furthermore, the prevalence of low-income levels among Ghanaian households poses difficulties in affording energy-efficient appliances or renewable energy systems (Diawuo et al., 2018). Moreover, inadequate infrastructure, typified by unreliable electricity provision and insufficient waste management systems, can impede endeavors to propagate energy efficiency and sustainability within the residential sector (Twerefou & Abeney, 2020). Lastly, the lack of effective enforcement looms as a challenge; despite the formulation of energy efficiency regulations for household appliances, their impact is limited due to lax enforcement mechanisms (Sakah et al., 2019).

3.2.1. Energy Efficiency Programs to Enhance Sustainable Energy Consumption

In Ghana, the residential sector has been the focus of multiple efforts aimed at boosting energy efficiency. The need for these initiatives arose as a response to the severe power shortages that Ghana experienced due to droughts in the 1980s and 1990s (IO, 26 May 2023). The residential sector's significance in these efforts has been duly recognized (IO, 26 May 2023). Notably, one pivotal aspect involves the establishment of Appliance Performance Standards. Ghana has introduced regulations aimed at enhancing energy efficiency in common household appliances like refrigerators, freezers, and room air conditioners (Energy Commission, 2020). These regulations are designed to cut down on energy consumption by defining minimum energy performance benchmarks for these appliances (Diawuo et al., 2018).

Ghana has undertaken the implementation of protocols involving standards and labeling initiatives tailored for household appliances, imparting vital information to consumers regarding the energy efficiency attributes of these products. An investigative study conducted in Tema, Ghana, adopted a dual-pronged approach, entailing a survey on residential electricity consumption coupled with comprehensive monitoring of electricity usage across 60 households, thereby illuminating the panorama of electricity consumption on a city-wide scale within Ghanaian residences (Sakah et al., 2019). Notably, the residential sector in Ghana constitutes a notable stakeholder, contributing a substantial 47% share to the comprehensive final energy consumption (IO, 26 May 2023). The core tenet of energy efficiency programs hinges on the curtailment of energy consumption within the residential sector through the active advocacy for the incorporation of energy-efficient appliances and practices (Diawuo et al., 2018). An additional significant aspiration of these programs' centers on the enhancement of sustainability. By channeling efforts towards the mitigation of greenhouse gas emissions and the propagation of renewable energy adoption, these initiatives strive to bolster the sustainability paradigm within the energy landscape (Twerefou & Abeney, 2020).

By reducing energy consumption, energy efficiency programs can help households save money on their electricity bills (Twerefou & Abeney, 2020). Energy efficiency programs can also help improve access to electricity by reducing demand and increasing the reliability of the electricity supply (Diawuo et al., 2018). Fulfilling international commitments: Through the reduction of greenhouse gas emissions, energy efficiency programs have the potential to assist Ghana in aligning with its global obligations concerning emissions (Energy Commission, 2020). Government policies hold a pivotal role in fostering energy efficiency within Ghana's residential sector. Notably, the government has taken active strides in executing energy efficiency programs with the primary goal of curtailing energy consumption within residential areas (IO, 26 May 2023). These initiatives are designed to propagate the utilization of energy-efficient appliances and practices. To this end, the government has established regulatory frameworks encompassing energy efficiency for commonplace household appliances, including refrigerators, freezers, and room air conditioners. The essence of these regulations is to affect a reduction in energy consumption, realized by stipulating minimum energy performance benchmarks for these appliances (Sakah et al., 2019). The government's engagement extends to the enforcement of standards and labeling protocols, aimed at providing consumers with essential insights into the energy efficiency attributes of various appliances (Diawuo et al., 2018).

The government is working on developing building codes that promote energy efficiency in commercial and public buildings (ACTC, 26, May 2023). Ghana has participated as a signatory to global accords that advocate for the advancement of energy efficiency, notably including the United Nations Framework Convention on Climate Change (UNFCCC) and the ECOWAS Energy Efficiency Policy (Twerefou & Abeney, 2020). Efforts to enhance energy efficiency have the potential to yield significant energy savings in buildings, industries, and transportation. According to a recent report from the International Energy Agency (IEA), the buildings sector stands out as having the greatest potential for conserving energy compared to other sectors (IEA, 26 May 2023). The report highlights that energy-efficient buildings can be more cost-effective to heat, cooling, and operate. Another IEA report estimates that a substantial

80% of the economic potential for boosting energy efficiency in buildings remains untapped (IEA, 27 May 2023).

This underscores a substantial opportunity to achieve energy savings within this sector. Strategies for improving energy efficiency in buildings include using energy-efficient lighting and appliances, improving insulation, and using renewable energy sources (IEA, 27 May 2023). The IEA report also states that the industry has significant potential for energy savings (IEA, 27 May 2023). Energy-efficient manufacturing plants can make products at lower costs. Strategies for improving energy efficiency in industries include using more efficient equipment and processes, improving insulation, and using renewable energy sources. Transportation serves as a substantial energy consumer and thus offers notable opportunities for energy conservation (EG, 27 May 2023). Approaches aimed at enhancing energy efficiency within the transportation sector encompass the adoption of more fuel-efficient vehicles, the advocacy for public transportation utilization, and the promotion of pedestrian and bicycling activities (CXA, 27 May 2023).

Energy efficiency measures have the potential to save significant amounts of energy in buildings, industries, and transportation in Ghana. Here is an analysis of the potential for energy savings in each sector. The residential sector in Ghana constitutes 47% of the total final energy consumption (IO, 28 May 2023). A substantial potential for energy savings can be unlocked through the reduction of inefficiencies within this sector. Notably, the Energy Commission of Ghana has made a plea for assistance in enhancing energy efficiency within commercial and public structures across the nation (ACTC, 28 May 2023).

However, a prevailing challenge pertains to the absence of prevailing regulations and benchmarks concerning the design and construction of energy-efficient buildings in Ghana, which impedes progress in energy efficiency within this domain (ACTC, 28 May 2023). As Ghana strives to achieve sustainable energy accessibility for all, the proficient management of energy intensity within manufacturing, transport, and industries through energy efficiency strategies emerges as particularly crucial (SEforAll, 28 May 2023). A research study conducted within Ghana's most expansive industrial region had the objective of augmenting comprehension concerning industrial energy efficiency and the management approaches pertinent to the nation (Apeaning, 2012). The outcomes of the study revealed a substantial scope for conserving energy by integrating energy-efficient technologies and adopting corresponding practices. In parallel, transportation, recognized as a noteworthy energy consumer, holds considerable potential for effecting energy savings (Diawuo et al., 2018). Strategies for improving transportation energy efficiency include using more fuel-efficient vehicles, promoting public transportation, and encouraging walking and biking (Twerefou & Abeney, 2020).

There are several examples of energy-efficient transportation in Ghana. A study found that integrating biofuels into the transportation sector in Ghana can contribute to reducing greenhouse gas emissions (Saisirirat et al., 2022). The Government of Ghana has publicly declared its intention to formulate an Energy Transition Plan in collaboration with Sustainable Energy for All and Bloomberg Philanthropies, aimed at guiding the nation towards achieving comprehensive energy access and mapping a trajectory towards net-zero greenhouse gas emissions (SEforAll, 28 May 2023). This strategic blueprint will offer a comprehensive framework for Ghana's endeavors. It underscores the pivotal significance of enhancing energy efficiency within the transportation domain as a crucial facet of Ghana's ongoing energy transition. A conducted study discerned that the cubic model presents the most suitable fit for characterizing automotive energy demand in Ghana, thereby highlighting an exponential trajectory for future automotive energy demand (Annan et al., 2015). This observation implies a pressing necessity for more proficiently designed vehicles in the Ghanaian context. Ghana's resolute commitment pertains to the curbing of emissions, particularly emanating from the transportation sector, to align with the global objective of maintaining the rise in temperature below 1.5 degrees Celsius (EJN, 28 May 2023). In Ghana, there is a range of energy-efficient construction materials available for utilization. Notably, efforts to conserve energy in the commercial sector have largely focused on adopting efficient lighting methods over time (ACTC, 28 May 2023). This indicates that incorporating energy-efficient lighting can be an effective strategy for curbing energy usage in buildings. A study investigated various construction techniques and material choices within a standard building, aiming to reduce energy needs (Annan et al., 2015). The results highlighted the potential for substantial energy savings by using low-energy building materials. An innovator in Ghana has ingeniously created affordable homes from recycled plastic waste, which not only cut costs but are also energy-efficient, benefiting from natural cooling due to the materials used (XN, 28 May 2023). Ghana's energy landscape encompasses both renewable and non-renewable sources, with significant government involvement in energy generation, distribution, and trading (EIA, 2023). Analysis of Ghana's primary energy consumption trends reveals an average annual increase of 6.28%, climbing from 0.13 quadrillion Btu in 2002 to 0.39 quadrillion Btu in 2021 (Knoema 2021). Ghana's consumption of electricity, which makes up a portion of the country's overall energy consumption, has been on the rise recently.

In Ghana, 91% of urban residents and 50% of rural residents are connected to the electricity grid, making up an access rate of 86.63% (ITA, 2022). Ghana's total annual production of electric energy from all sources is 13 billion kWh or 134% of domestic demand. Ghana still exchanges energy with other nations despite this (WD, 2020). Fossil fuels, such as oil and gas, and hydro sources account for most of Ghana’s energy consumption. In 2015, fossil fuels accounted for 41.6% of electricity production, while hydropower accounted for 46.9% (UNEP, 2015) Nevertheless, it is noteworthy that Ghana possesses the inherent capability to domestically generate an ample supply of energy to fulfill its entirety of demands, as demonstrated by its mean yearly per capita energy consumption of 285 kWh (WD, 2020). Overseeing the technical facets of Ghana's electricity, natural gas, and renewable energy domains is the Energy Commission, vested with the mandate of ensuring the supervision, advancement, and utilization of the nation's energy resources (ECG, 2022).

Table 3.2. Primary Energy Consumption of Ghana (2010 to 2020)

Fuel Type	2010 (quadrillion Btu)	2011 (quadrillion Btu)	2012 (quadrillion Btu)	2013 (quadrillion Btu)	2014 (Quadrillion Btu)	2015 (quadrillion Btu)	2016 (quadrillion Btu)	2017 (quadrillion Btu)	2018 (quadrillion Btu)	2019 (quadrillion Btu)
Coal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Natural Gas	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Petroleum and Other Liquids	0.30	0.33	0.38	0.38	0.35	0.37	0.38	0.38	0.40	0.38
Other Renewables	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
Hydroelectricity	0.14	0.15	0.15	0.17	0.19	0.19	0.20	0.20	0.19	0.19
Total	0.45	0.48	0.54	0.55	0.54	0.56	0.58	0.58	0.60	0.58

(Source: Energy Commission of Ghana, Ghana Key Energy Statistics Handbook)

From the table above, coal consumption was 0. 003 quadrillion Btu in 2010 and remained the throughout the ten-year period, that is from 2010 to 2019. Natural gas consumption in Ghana was the same as coal consumption with an amount of 0.003 quadrillion Btu being the same from the years 2010 through to 2019. For Petroleum and other liquids, 0.30 quadrillion Btu was consumed in 2010 and by 2019 the figure increased to 0.38 quadrillion Btu. Petroleum and other liquids appear to be the fuel type that is highly consumed throughout the ten-year period from 2010 to 2019. Renewables, on the other hand, was the least consumed energy form in 2010 with 0.001 quadrillion Btu but increased steadily from this period to 2019 with an amount of 0.003 quadrillion Btu. Hydroelectricity consumption in 2010 was 0.14 quadrillion Btu but also increased to 0.19 quadrillion Btu in 2019. In total Ghana's energy consumption over a ten-year period from 2010 to 2019 increased from 0.45 quadrillion Btu to 0.58 quadrillion Btu.

3.3. Energy Costs and Affordability

Exceeding a population of 1.5 billion individuals globally, primarily concentrated in the Global South, faces a dearth of access to contemporary energy resources, predominantly for cooking requirements within their households. To address this exigency, an investigative endeavor was undertaken, concentrating on the cooking realm within the Global South, with an explicit emphasis on rural communities. The investigation's core objective involved discerning alternative energy sources, pertinent technologies, and complementary policy frameworks conducive to advancing clean cooking services, thus fostering heightened socioeconomic progress. Through a comprehensive analysis encompassing facets like technological attributes, cost dynamics, availability, climate-consciousness, business models, and local competencies, the study formulated recommendations directed at nurturing clean cooking policies. According to the study, creative solutions like the pay-as-you-go LPG model, cost-effective ethanol distribution methods, and the use of waste-product pellets could make clean cooking more widely adopted (Vassiliades et al., 2022). According to the Energy Commission of Ghana, Ghana's per-capita electricity consumption was 466 kWh in 2019, which was less than the 535-kWh average for Sub-Saharan Africa. Additionally, this is considerably less than the 3,896-kWh global average. In Ghana, the percentage of people with access to electricity has increased over the past ten years, reaching about 85% in 2019. For many households and businesses in Ghana, access to dependable and reasonably priced electricity is still a problem (Energy Commission-Ghana, 2020).

In comparison to other African nations, Ghana has a high cost of electricity. The International Energy Agency (IEA) estimates that Ghana's residential electricity rates will be around $0.17 per kWh in 2020. This is more expensive than the typical Sub-Saharan African rate, which in the same year was around US$0.14 per kWh. The high expense of fuel and the limited investment in renewable energy sources are two key factors contributing to the elevated cost of electricity in Ghana (Trimble et al., 2016). Depending on their income levels, different households and businesses across Ghana can manage varying amounts of energy expenditure. As per data provided by the Ghana Statistical Service, the average monthly income in the country for the year 2019 was approximately GH2, 429 (equivalent to US$416). With 60% of the population surviving on less than GH2, 000 (US$342) per month, Ghanaians generally make less money than this. As a result, energy expenses for many households can significantly reduce their already meager income (GSS, 2019).

Firewood and charcoal are the two most popular types of cooking fuel in Ghana, with LPG coming in third. However, the adoption of other clean cooking fuels like ethanol, biogas, electricity, and advanced cook stoves is still very low, accounting for just 1% of all households in Ghana. Although cleaner alternatives have higher upfront costs, low-income households cannot afford them due to their higher fuel costs (Pelizan, 2019b). In Ghana, SMEs have a difficult time finding an affordable power source. Self-generation options may be able to reduce these issues to some extent, but SMEs must select solutions that offer sizable cost savings. Throughout the progression of renewable energy technology, the transition, whether complete or partial, from conventional energy sources to renewable alternatives presents Small and Medium-sized Enterprises (SMEs) with noteworthy opportunities for cost reduction. In this context, SMEs are tasked with factoring in pivotal elements influencing their decisions on investing in renewable energy. These elements encompass the capacity attributes of renewable energy technologies, the prevalent tariff structures governing conventional power supply, the dependability of established conventional systems, and the capital outlays requisite for establishing renewable energy generation facilities (Ofori et al., 2022).

Ghana has recently undergone revisions to its renewable energy legislation, embodied in Act 835, aimed at the ambitious objective of attaining a renewable energy contribution of 10% by the year 2020. Nonetheless, the prevailing reality is that the utilization of solar Photovoltaic (PV) technology merely constitutes a minor fraction, accounting for less than 2% of the country's energy composition. This modest incorporation is principally attributed to several substantial barriers that impede the investment dynamics surrounding solar PV. These impediments encompass the formidable financial outlay associated with installation and upkeep, a scarcity of extended-term capital funding options, the accessibility of affordable consumer financing avenues, and an insufficient support framework for initiatives pertaining to research and development within this domain (Sackey et al., 2020). Commercializing solar home solutions with a pay-as-you-go (PAYG) business model could make it easier for rural off-grid households to access electricity. By using mobile money to make small payments, the PAYG model enables the population that is still without electricity to lease or rent small stand-alone photovoltaic systems. The client acquires ownership of the solar kit after a payment period that typically lasts between 12 and 36 months. (Pelizan, 2019a).

For households, especially those living off the grid, the lack of access to electricity in Ghana's rural areas poses a serious problem. Commercializing solar home solutions with a pay-as-you-go (PAYG) business model could make it easier for rural off-grid households to access electricity. With minimal up-front costs, a simple and quick installation process, and a practical and adaptable payment system, this solution offers a fundamental and affordable electricity service. As a result, their purchasing power may rise along with household and small business productivity (Pelizan, 2019a). In Ghana, securing a cost-effective power supply remains an intricate challenge for Small and Medium-sized Enterprises (SMEs). While self-generation alternatives might alleviate this issue partially, SMEs must strategically adopt solutions that yield substantial financial advantages. Within the trajectory of renewable energy technology, SMEs can leverage substantial cost reductions by fully or partially transitioning from conventional energy sources to renewable counterparts. Facilitating this transition necessitates not only favorable policies but also proactive efforts to educate SMEs about the significance and technical requisites of renewable energy adoption. Such measures hold the potential to enhance SMEs' competitiveness and concurrently alleviate production costs (Ofori et al., 2022). Solar photovoltaic (PV) technology encounters prominent investment obstacles in Ghana, primarily encompassing the substantial financial outlays linked to installation and maintenance, the scarcity of sustainable long-term capital funding avenues, the dearth of accessible consumer finance at reasonable terms, and the lack of support for research and developmental endeavors. Elevating investments in renewable energy holds the potential to mitigate electricity expenses and elevate the business competitiveness landscape (Sackey et al., 2020).

3.3.1. Energy Efficiency Measures to Reduce Energy Costs and Enhance Affordability

The Ghanaian government has put in place several energy subsidy programs to lessen the effects of high energy costs on low-income households. One such program is the Lifeline Tariff Scheme, which offers households that use less than 50 kWh of electricity per month a discounted tariff rate. In contrast to the standard residential rate of GH0.3385 (US$0.058) per kWh, the Lifeline Tariff rate for 2020 was set at GH0.2255 (US$0.039) per kWh (Berkouwer et al., 2022). The government has also implemented the Free SHS (Senior High School) program, which offers free electricity to all public senior high schools in Ghana, in addition to the Lifeline Tariff Scheme. The goal of this program, which was launched in 2015, is to lessen the financial burden on parents of senior high school students. Many more Ghanaian children now have access to education thanks to the program, but it has also drawn criticism for its effects on the country's budget (Berkouwer et al., 2022). Despite these initiatives, many businesses continue to face difficulties due to Ghana's high energy costs. Small and medium-sized businesses (SMEs) in particular frequently struggle to find affordable and trustworthy energy.

According to data from the World Bank, the price of electricity for businesses in Ghana in 2019 was approximately $0.19 per kWh. The average price per kWh in Sub-Saharan Africa is $0.15 US, so this is higher. The high cost of electricity can be a major impediment to the expansion and growth of SMEs, which are a major force behind economic growth in Ghana (UNEP, 15 June 2023). The information mentioned above suggests that Ghana's energy affordability is a problem, particularly for low-income households. Cleaner alternatives do exist, but because they are more expensive up front, they are not frequently used. To make these options more accessible and affordable for low-income households, the government must put in place efficient policies and financing ideas. Furthermore, delivering housing with the right technology and design can be economical and environmentally responsible. To make clean cooking more widely used, the government can investigate cutting-edge solutions like the pay-as-you-go LPG model, the cost-effective distribution of ethanol, and the use of pellets made from waste products.

By adopting energy-saving techniques and embracing renewable energy sources, Ghana could potentially reduce energy costs and enhance affordability. Fossil fuels currently dominate Ghana's energy sector, accounting for over 80% of its primary energy requirements. This reliance creates challenges with high energy expenses and affordability concerns. However, Ghana has a valuable opportunity to address these issues by implementing strategies to boost energy efficiency and integrate renewable sources. This approach could substantially cut down on energy costs, improve affordability, and contribute to sustainable development efforts (Amoah et al., 2022). Ghana's residential sector is one of the most promising energy efficiency initiatives, but traditional biomass fuels are still used for heating and cooking. The Ghana

Energy Commission has started a program to give Liquefied Petroleum Gas (LPG) stoves to households to encourage the use of cleaner and more effective heating and cooking methods.

Utilizing LPG stoves could lessen reliance on conventional biomass fuels and enhance indoor air quality. The adoption of energy-saving lighting, appliances, and construction materials may contribute to a decrease in the amount of energy used in residential structures, resulting in lower energy costs for households (Mawusi et al., 2023). Ghana's industrial sector emerges as a key domain necessitating the implementation of energy efficiency strategies. Of salience in the energy efficiency agenda is the industrial sector, accounting for approximately 30% of the nation's energy consumption. This sector has been a focal point for the initiation of various endeavors aimed at fostering energy efficiency.

To illustrate, the Ghana Energy Commission has launched the Energy Efficiency and Conservation program, envisioning the promotion of energy-efficient technologies and practices across all industrial domains in the country. Additionally, the Ghana National Petroleum Corporation (GNPC) has established an Energy Services Company (ESCO) to offer energy-efficient solutions to industries nationwide. These concerted initiatives hold the potential to yield notable reductions in industrial energy consumption, thereby concomitantly contributing to the moderation of energy costs (EEI, 16 June 2023).

The incorporation of renewable energy sources holds significant promise in the context of Ghana's energy landscape, carrying the potential to substantially mitigate energy costs and enhance affordability. The country possesses ample solar, wind, hydro, and biomass resources, among other renewable alternatives. Nonetheless, the application of renewable energy technologies has been limited within Ghana, primarily attributed to the dearth of comprehensive policy and regulatory frameworks, upfront cost challenges, and constrained access to financing. Nonetheless, a series of concerted endeavors aimed at advancing renewable energy utilization are evident. Illustratively, Ghana's legislative infrastructure for the advancement, advocacy, and oversight of renewable energy finds expression through the Renewable Energy Act enacted in 2011. Furthermore, the government has initiated various programs to bolster the adoption of renewable energy, exemplified by the Renewable Energy Master Plan delineating a strategic trajectory for the progression of renewable energy within the nation (Kuamoah, 2020a). Renewable energy, particularly in the form of solar energy, stands as a promising avenue within Ghana's energy landscape. The country exhibits one of the most substantial potentials for harnessing solar energy, as indicated by an average irradiance of 5 Kilowatt-hours per square meter per day, highlighting the abundance of this resource.

However, solar energy only accounts for 2% of the nation's electricity generation capacity. Ghana's use of solar energy technologies could help the nation become less dependent on fossil fuels and result in lower energy costs for both homes and businesses. Moreover, the deployment of solar home systems and mini-grids in rural areas bears the potential to significantly augment energy accessibility and affordability for rural households (Asumadu-sarkodie & Owusu, 2016). The implementation of energy efficiency programs along with the integration of renewable energy sources holds considerable promise in significantly diminishing energy expenses and enhancing affordability within Ghana. The realization of reduced energy costs for both residential and industrial domains hinges upon the adoption of energy-efficient technologies and practices. Furthermore, the endorsement of renewable energy source integration contributes to this prospect. This collective endeavor aligns with the nation's commitment to sustainable development. Nevertheless, the effective implementation of these strategies mandates the establishment of robust policy and regulatory frameworks, accessibility to financial resources, and widespread societal acceptance.

3.4. Energy Sector Contribution to GDP and Employment

The energy sector plays a significant role in Ghana's gross domestic product (GDP) and employment. According to data from the World Bank, the sector contributed approximately 13.7% to Ghana's GDP in 2020 (Kipkoech et al., 2022). This indicates a substantial direct contribution to the overall economic output of the country. In terms of employment, the renewable energy sector alone employed over 5,000 people in Ghana in 2019, according to the International Renewable Energy Agency (IRENA). However, this figure does not include employment in other sub-sectors of the energy sector, such as oil and gas (Brew-hammond & Essandoh, 2013). It is evident that the energy sector indirectly supports this sector by providing the necessary power supply for industrial activities. The energy sector directly and indirectly contributes to employment opportunities in Ghana. The Ghana Statistical Service reported that the total employment in the energy sector rose from 0.7% in 2010 to 1.2% in 2020. This indicates a gradual increase in job opportunities within the sector. The sector provides employment in various sub-sectors, including electricity generation, transmission, and distribution, as well as oil and gas exploration and production (Honorati and de Silva, 2016).

3.5. Energy Import and Export

The aggregate energy imports for the year 2019 stood at 5,129.3 Ktoe, reflecting a decrease of 4.6% from the previous year's figure of 5,377.7 Ktoe in 2018. The concept of import dependency pertains to the ratio of overall net imports (comprising imports minus exports) of oil, solid fuels, and natural gas to the complete energy supply. In Ghana, the import dependency escalated from -35.9% in 2018 to -50.9% in 2019, signifying the nation's role as a net energy exporter. Petroleum products emerge as the primary energy commodities imported by the country. In 2019, petroleum products constituted the majority share of 71.9% in the total energy imports, although this figure had been 84.2% in 2018. This underscores the nation's substantial reliance on imported petroleum products to satiate its energy requisites (National Energy Statistics 2020).

TES	2010	2015	2016	2017	2018	2019	2020	2021
Crude Oil	199	5,458	4,706	8,547	9,054	10,410	9,752	8,022
Natural Gas	0	665	592	850	985	1,394	2,398	2,717
Solar	0	0	2	2	3	4	5	11
Hydro	601	503	478	483	517	624	627	647
Biomass	3,207	3,618	3,602	3,858	4,222	4,132	4,274	4,190
Total	4,007	10,244	9,381	13,741	14,781	16,564	17,056	15,586

Figure 3.1. Production of Primary Fuels (Ktoe)

(Source: Ghana Key Energy Statistics Handbook (2022))

From 4,007 ktoe in 2010 to 15,586 ktoe in 2021, primary fuel production increased at a 13.1% average annual growth rate. primarily due to an increase in crude oil production. Between 2010 and 2021, the average annual growth rate for crude oil production was 39.9%, reaching 8,022 ktoe.

Year	LPG	Gasoline	Kerosene	ATK	Gas Oil	DPK	HFO	Total
2000	35	387	30	-	363	-	-	816
2001	36	389	22	-	354	-	-	801
2002	32	371	49	-	298	-	-	750
2003	17	232	35	-	286	-	-	569
2004	11	255	-	-	313	-	-	579
2005	7	167	-	-	404	-	-	578
2006	68	360	100	79	780	-	-	1,387
2007	47	275	67	43	807	-	-	1,238
2008	68	255	136	156	579	-	-	1,194
2009	151	563	78	84	970	-	-	1,845
2010	148	570	-	-	872	-	-	1,590
2011	178	713	-	-	1,201	18	-	2,109
2012	242	812	-	96	1,309	115	-	2,573
2013	204	1,017	-	41	1,639	-	44	2,946
2014	236	1,254	-	112	1,742	-	49	3,394
2015	198	1,182	-	109	2,161	-	-	3,650
2016	178	1,236	-	113	1,720	-	386	3,632
2017	202	1,304	-	181	1,781	-	608	4,076
2018	315	1,324	-	184	1,753	-	649	4,224
2019	275	1,265	-	181	1,742	-	366	3,829
2020	262	1,625	-	80	1,937	-	63	3,965

Figure 3.2. Petroleum Products Import

(Sources: GODI, 26 August 2022)

Petroleum product production has however decreased from 1,028 kt in 2000 to 580 kt in 2020. The country's lowest level of petroleum product production was recorded in 2015, with 89 kt produced.

Year	LPG	Gasoline	Kerosene	ATK	Gas Oil	RFO	Total
2000	10	239	52	108	358	262	1,028
2001	7	286	98	64	353	261	1,070
2002	24	346	61	82	447	196	1,155
2003	53	434	110	86	507	164	1,352
2004	66	553	111	107	568	199	1,604
2005	75	567	88	119	486	205	1,541
2006	36	294	65	46	294	156	891
2007	67	493	122	66	398	49	1,195
2008	55	391	169	21	361	225	1,222
2009	14	135	49	1	103	25	327
2010	32	338	71	117	293	97	946
2011	45	344	53	116	310	91	958
2012	27	158	21	48	122	79	454
2013	26	167	15	60	113	43	424
2014	3	40	4.5	9	28	44	129
2015	2	32	0.2	18	28	9	89
2016	114	244	24.5	38	255	64	739
2017	114	6	2	0	6	4	133
2018	88	102	33	22	114	32	390
2019	70	125	12	80	198	205	690
2020	85	66	35	28	150	216	580

Figure 3.3. Production of Petroleum Products

(Sources: CEIC, 26 August 2022)

Over the span of two decades, specifically, from 2000 to 2020, there has been a noticeable decline in the export of Liquefied Petroleum Gas (LPG). This decline is characterized by a compound annual growth rate of 3.4%, leading to a reduction from 6 kt in 2000 to 3 kt in 2020. However, the most pronounced reduction in export volumes occurred within the recent three years. In a similar vein, Aviation Turbine Kerosene (ATK) export figures displayed an increase from 95 kt in 2000 to 205 kt in 2019. Nevertheless, a significant decrease to 113 kt in 2020, amounting to a 44.9% decline, was anticipated. The root cause of this decline in 2020 can be attributed to the imposition of international travel restrictions stemming from the global COVID-19 pandemic. Moreover, during the period spanning 2000 to 2020, the export volumes of fuel oil registered a diminishing trend, manifesting a compound annual rate of reduction at 0.5% (Ghana National Energy Statistics 2021).

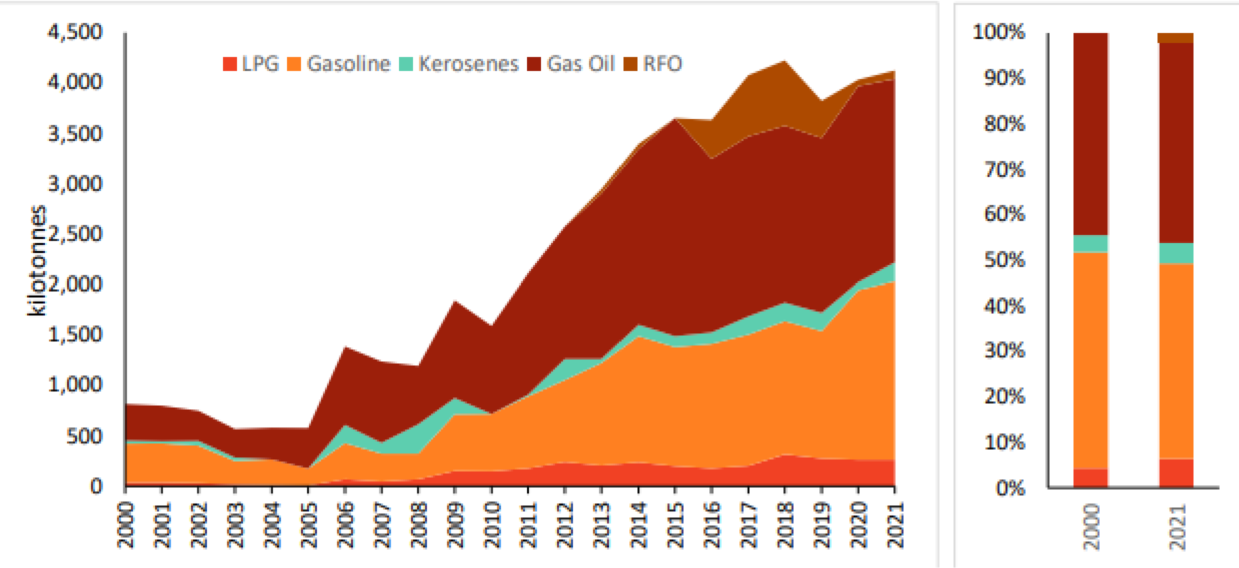

Figure 3.4. Petroleum Products Export

(Source: Ghana Key Energy Statistics Handbook (2022))

During the year 2020, the quantity of electricity exported exhibited a growth of 25.9% as compared to the preceding year 2019. The figures stand at 1,430 GWh for 2019 and 1,801 GWh for 2020. Conversely, the scenario for electricity imports took a divergent route, showing a considerable decline. This decline led to a reduction from 320 GWh in 2017 to 58 GWh in 2020, demonstrating a noteworthy compound annual decrease of 43.4%. Ghana has traditionally maintained a preference for exporting higher-grade oil while opting to import crude oil for economic considerations. In the time frame from 2000 to 2008, the cumulative imports of crude oil witnessed an ascent of 53.8%.

However, this upward trend experienced a reversal in 2009 with a decline of 50.3%. Subsequently, spanning the period from 2010 to 2020, the import of crude oil observed a substantial drop of about 58.4%. In the specific year 2020, the aggregated volume of crude oil exported accounted for 67,458 thousand barrels. Notably, there was a 5% decrease in crude oil exports in 2020 in comparison to the preceding year, with 2019 registering a total of 70,985 thousand barrels (provided data sources).

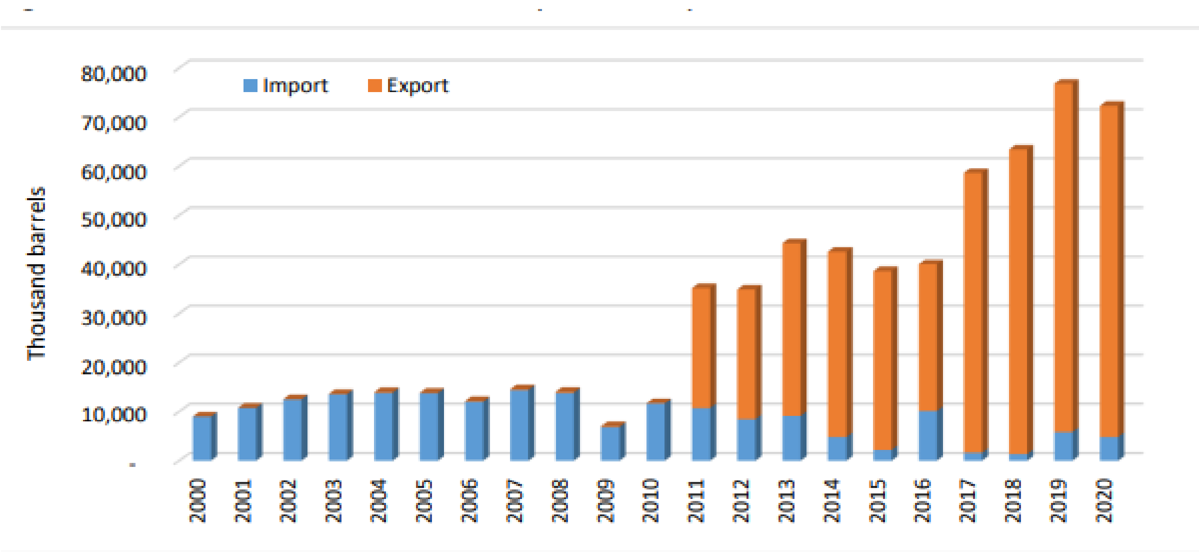

Figure 3.5. Crude Oil Import and Export Trends From 2000 to 2020

(Source: National Energy Statistics of Ghana 2021)

The West African Gas Pipeline (WAGP) serves as the conduit for the transportation of natural gas from Nigeria to Ghana. However, recent years have witnessed a decline in the import of natural gas due to the rise in domestic production. Until the year 2014, Ghana had not initiated any significant natural gas production endeavors. Subsequently, from the year 2014 onwards, the country commenced its natural gas production journey with an initial output of 2.0 Btu. This production volume has demonstrated consistent progress over successive years, concomitantly with a reduction in the quantum of imported natural gas. Predominantly, the imported gas is allocated for electricity generation purposes, with a minor fraction, accounting for less than 2%, earmarked for non-power applications. In the year 2020, the aggregate import of natural gas amounted to 24.4 tBtu, reflecting a growth of 2.5% when juxtaposed with the import quantity of 23.8 tBtu documented in 2019. This elevation in imports is attributed to the surge in natural gas production, which escalated from 55.3 tBtu to 95.2 tBtu during the year 2020 (as reported by the National Energy Statistics in 2021).

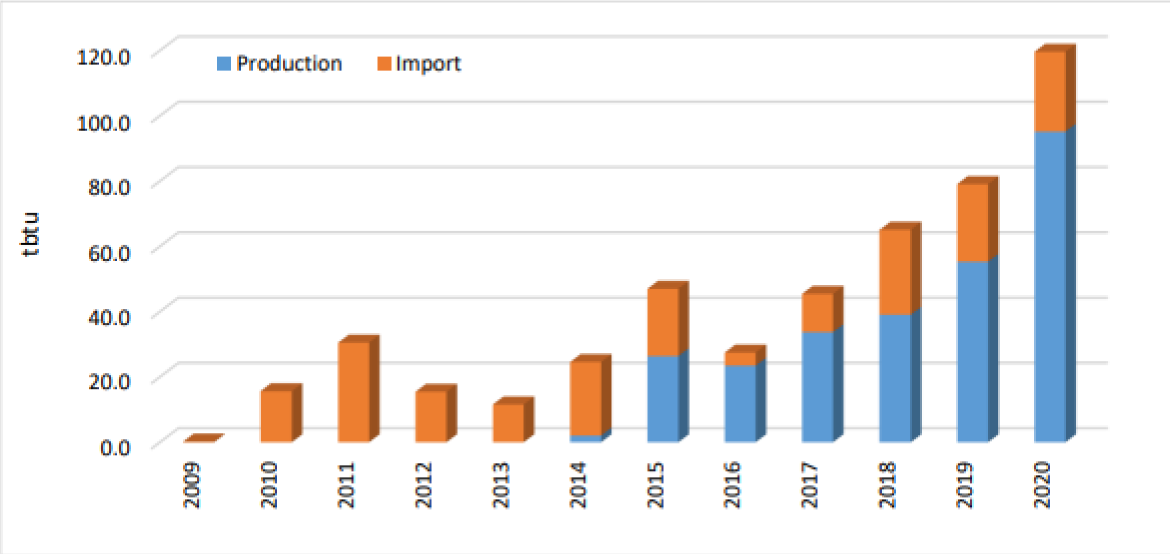

Figure 3.6. Natural Gas Production and Import

(Source: National Energy Statistics of Ghana, 2021)

3.6. Energy Access of Ghana

Energy access is critical for development and poverty alleviation. It is essential for human well-being and economic activity. The world's 13% of people lack access to electricity (OWID, 3 November 2022). As of the end of 2016, according to an assessment from the Energy Commission made in 2017, 83% of the population had access to electricity, while the remaining 17% had no access and must rely on traditional energy sources such as charcoal, wood fuels, and kerosene. This is about three and a half as much access to power as there was in 1990 (23%) and almost twice as much as in 2000 (43%) (Bukari et al., 2021). Although Ghana's energy access situation is currently improving, there are still numerous issues that need to be resolved. One concern is that many individuals find it difficult to afford energy because of its high cost. The absence of infrastructure in rural places makes it impossible to provide dependable electricity access, which is another problem. These problems are being addressed by the Ghanaian government, which has set 2030 as the timeline for achieving universal access to energy (Kumi, 2017).

Ghana's vast rural population is one factor. Most rural citizens in the nation lack access to the national grid. Even if they did, it's possible that they wouldn't be able to pay the exorbitant prices of electricity. The underdeveloped state of Ghana's energy industry is another factor. The nation lacks the necessary infrastructure to grant widespread access to energy. Lack of skilled people makes this issue worse (Kumi, 2017). The enhancement of renewable energy utilization emerges as a pivotal domain with potential for refinement. As of 2020, a mere 1.1% of Ghana's electricity emanates from renewable sources; however, this proportion holds the promise of augmentation.

Ghana is endowed with substantial solar and wind energy resources, both bearing the capacity to furnish a substantial quantum of power. The escalated integration of renewable energy sources would not only amplify energy accessibility but also effectuate a reduction in emissions of greenhouse gases. Furthermore, an expansion of access to clean cooking fuels and efficient stoves represents another arena ripe for developmental intervention (Kuamoah, 2020b). It is imperative to recognize the involvement of the local community as an integral facet of the energy planning trajectory. Such community participation is poised to substantially fortify the sustainability of energy initiatives, alongside the adoption of technologies that might otherwise encounter challenges in garnering acceptance (Bukari et al., 2021).

Table 3.3. Percentage of Ghanaians with Access to Electricity from 2012 to 2021

Year	Percentage %
2012	56.51
2013	70.70
2014	78.30
2015	74.08
2016	79.30
2017	79.00
2018	80.40
2019	83.50
2020	85.87
2021	86.30

(Source: Generated by Author Using Data from our world in data website, “Ghana: Energy Country Profile”)

From the table above, electricity access in Ghana was 56.51% in 2012, it increased to 70.70% in 2013 then rose to 78.30% in 2014. However, in 2015 there was a decrease from 78.30% to 74.08%, electricity access increased again to 79.30% in 2016 and then decreased slightly to 70% in 2017. By 2018 electricity access in Ghana had reached 80.40% and then increased to 83.50% in 2019. In 2020, the figure rose to 85.87%and then 86.30% in 2021.

Table 3.4. Percentage of Ghanaians with Access to Clean Energy for Cooking from 2012 to 2021

Year	Percentage %
2012	18.70
2013	19.60
2014	20.50
2015	21.10
2016	21.80
2017	21.90
2018	22.20
2019	22.40
2020	22.20
2021	30.3

(Source: Generated by Author Using Data from our world in data website, "Ghana: Energy Country Profile")

From the table, clean energy access was 18.70% in 2012 which increased to 19.60% in 2013, in 2014, it increased to 20.50% and then to 21.10% in 2015. Meanwhile, 2016 and 2017 saw slight increment with 21.80% and 21.90% respectively, by 2018 access to clean for cooking had risen to 22.20% and 22.40% in 2019. In 2020 however, the figure decreased from 20.40% to 22.20% and finally 2021 saw an increase from 22.20% to 30.3%.

CHAPTER FOUR

RELATIONSHIP BETWEEN ENERGY USE AND THE ENVIRONMENT

4.1. Categories of Environment Impacts of Energy Use

4.1.1. Emissions of Greenhouse Gases and Air pollution

The common use of open fires and traditional cook stoves in Ghanaian homes significantly contributes to air pollution. Over 80% of Ghanaians, according to the World Health Organization (WHO), cook with solid fuels, which contaminates the air indoors (Dickinson et al., 2015). Volatile Organic Compounds (VOCs), particulate matter (PM), and carbon monoxide (CO) are among the harmful pollutants that are released during the combustion of solid fuels like wood, charcoal, and agricultural waste (Pennise et al., 2009).

For women and children, exposure to indoor air pollution increases the risk of respiratory illnesses. Ghana's transportation industry relies heavily on fossil fuels, which causes air pollution. High levels of air pollutants are a result of outdated and inadequately maintained vehicles and insufficient emission control measures. Vehicles contribute to poor air quality in urban areas by emitting nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter (PM), and carbon dioxide (CO_2). Respiratory and cardiovascular diseases are among the health risks posed by air pollution from vehicle emissions (Kanyoke, 2004). A review of the effects of mining on the environment and human health in Ghana found that the country's mining operations have contaminated the air with dust and fumes from blasting and smelting (Emmanuel et al., 2018).

4.1.2. Water Pollution Resulting from the Production and Extraction of Energy

Water pollution in Ghana is largely caused by energy production techniques like thermal power generation. Oil and natural gas are the primary fossil fuels burned in thermal power plants to create electricity. Through atmospheric deposition or leaching into the soil and groundwater, these pollutants may eventually contaminate water bodies as a result of the combustion. Particulate matter, sulfur dioxide (SO_2), nitrogen oxides (NO_x), and other pollutants can cause acid rain and contaminate water sources (Bessah et al., 2021).

The Jubilee Oilfield, one of Ghana's offshore oil fields, has experienced oil spills that have contaminated the country's coastal waters and marine life, according to the Environmental

Protection Agency (EPA) of Ghana (GBN, 28 July 2023). According to Bessah et al., 2021 High concentrations of heavy metals, such as lead and mercury, were discovered in water samples taken from downstream of thermal power plants in Ghana. Small spills have been reported at the Tema oil refinery and at the ports of Tema and Takoradi, despite there being no significant spills in Ghanaian waters (ITOPF, 28 July 2023). Tankers and other large ocean-going vessels operating in Ghana's near-shore coastal waters have been blamed for the oil spills in the country's coastal waters (Afful, 1990). Due to the recent oil discovery, there are more civil and mechanical installations on the coastal waters, and oil spills do not spare these circumstances. Ghana has updated its environmentally sensitive atlas for coastal areas in preparation for any unanticipated oil spill incidents.

Furthermore, Ghana requires a coastal water management tool for oil spill simulation. Rapid simulations of hypothetical oil spills in Ghana's coastal waters have been conducted, and the results demonstrate the most efficient cleanup methods (Fiagbe, 2017). According to the World Bank's Water Resources Allocation Plan for Ghana, the energy industry uses about 11% of all the water used in the nation. Also, the Ghana Water Company Limited, the country's thermal power plants use water at a rate of 600 to 800 liters per kilowatt-hour of electricity produced The majority of Ghana's electricity is produced by thermal power plants, which account for 66% of all power production and 33% from hydropower (Opoku et al., 2022). The oil industry should be encouraged to adopt sustainable practices as part of efforts to prevent oil spills in Ghana's coastal waters. These efforts should also include stricter regulations and their enforcement. Protecting the nation's coastal waters and the communities that depend on them for their livelihoods is essential (Adjei Sowa, 2019).

4.1.3. Land Degradation and Habitat Destruction

In Ghana, energy extraction and production activities have significant negative environmental effects on land degradation and habitat destruction. These activities, which also include mining, oil and gas exploration, and building energy infrastructure, have had a negative impact on the nation's ecosystems and land. Natural resource extraction and processing frequently involve clearing large tracts of land, which causes habitat destruction and fragmentation, biodiversity loss, and soil degradation (Ashaley et al., 2011).

Ghana's surface mining industry particularly that for gold and bauxite, is one of the main causes of land degradation in the country. Data from the Ghana Chamber of Mines show that between 1990 and 2017, 41% of all forest losses were attributable to the mining industry. This startling statistic illustrates how mining operations have a significant negative impact on forest cover, leading to the loss of habitat and the displacement of wildlife. Land degradation is further exacerbated by the use of large machinery and the removal of mining waste, both of which frequently cause soil erosion (Akah, 2015). Oil and gas exploration is another energy-related activity that results in habitat destruction in Ghana. Marine ecosystems and habitats can be harmed by offshore drilling activities like seismic surveys, underwater blasting, and oil rig construction. Pipelines and onshore infrastructure construction also involve clearing land, which devastates terrestrial ecosystems by removing vegetation.

Due to the disruption of food chains and changes in resource availability, this destruction may have a domino effect on wildlife populations (J. L. Arthur & Amo-fosu, 2020). Land and habitat are significantly impacted by the building and running of energy infrastructure, such as power plants and transmission lines. These initiatives necessitate extensive land clearing and ecosystem alteration. For instance, large-scale hydropower project construction frequently entails flooding vast areas, which results in the loss of terrestrial and aquatic habitats.

The building of the Akosombo Dam on the Volta River in Ghana led to the eviction of thousands of people and the destruction of important wetland habitats (Ablo & Asamoah, 2018). Implementing efficient environmental management systems and regulations is essential to reducing the negative effects energy production and extraction have on the environment. Through a few policy initiatives and frameworks, Ghana has made efforts to address land degradation. The 2012 Forest and Wildlife Policy includes provisions for reforestation and the rehabilitation of degraded areas in order to ensure sustainable and responsible forest management. Similar specifications for environmental impact assessments and reclamation plans for mining activities are outlined in the Environmental Assessment Regulations and the Minerals and Mining Act of 2006 (Minerals Commission of Ghana, 2006).

4.2. Policies and Regulations Related to Energy and the Environment in Ghana

4.2.1. The Renewable Energy Act (2011)

The Renewable Energy Act (2011) was passed in order to establish a legal framework for Ghana's promotion, development, and use of renewable energy sources. By establishing feed-in tariffs and other incentives, this act promotes private sector involvement in renewable energy projects. By 2020, it wants to increase the proportion of electricity produced by renewable energy sources to 10%. Ghana has made great strides in this area, with renewable energy making up 2,942.99 GWh or 6.52% of all electricity generated in 2019 (Ghana, n.d.).

4.2.2. Regulations for Environmental Impact Assessment (EIA)

The evaluation of potential environmental effects of proposed projects is mandated by Ghana's EIA regulations. All sectors, including the energy sector, must abide by these rules, which are intended to promote sustainable growth and lessen negative environmental effects. Identifying potential effects, recommending mitigation strategies, and holding public hearings to involve stakeholders and solicit feedback from the general public are all part of the EIA process. Ghana aims to strike a balance between environmental protection and development by enforcing these regulations (Environment Ministry, 1999).

4.2.3. Climate Change Policy Framework (2017)

To direct Ghana's efforts in addressing the effects of climate change, the Climate Change Policy Framework was introduced in 2017. This policy acknowledges that different industries, such as agriculture, water resources, and coastal regions, are vulnerable to climate change. Enhancing adaptive capacity, cutting greenhouse gas emissions, and incorporating climate change into national development plans are its three main objectives. Subject to international support, Ghana has set a target to reduce emissions by 15% by 2030 (Pelicaric et al., 2008).

4.2.4. Energy Efficiency Regulations (2018)

Energy Commission of Ghana introduced energy efficiency regulations in 2018 to promote energy efficiency. These regulations demand that designated consumers, including businesses, office buildings, and public institutions, conduct energy audits and implement energy management systems. The goal is to save energy, lower energy costs, and lessen the effects energy use has on the environment. By encouraging energy efficiency and lowering greenhouse gas emissions, these regulations help Ghana achieve its goals for sustainable development (Ministry of Power, 2015).

4.3. Problems with the Legal and Policy Framework

For sustainable development, gaps and challenges in Ghana's policy and regulatory framework related to energy and the environment must be filled. The absence of a comprehensive energy policy that incorporates environmental concerns is one of the major gaps found. Although Ghana has made some strides in the development of renewable energy, there is still a need for a well-defined and comprehensive policy framework that outlines objectives, rewards, and rules to support renewable energy sources and lower carbon emissions (Kipkoech et al., 2022). Furthermore, there is a lack of coordination and harmonization among various institutions responsible for setting policy and enforcing regulations, which leads to mandates that overlap and regulations that are in conflict. This dispersed strategy impedes efficient and effective decision-making and can cause delays in project execution.

According to data from the Ghana Statistical Service, only 2.39% of the nation's total electricity production in 2019 came from renewable sources. This demonstrates the need for additional programs and regulations to support renewable energy sources like solar, wind, and hydroelectricity. Ghana can lessen its reliance on fossil fuels and subsequently cut greenhouse gas emissions by increasing the share of renewable energy in the country's energy mix (Energy Commission-Ghana, 2020). In conclusion, there are a few gaps and difficulties in Ghana's policy and regulatory framework related to energy and the environment that need to be fixed. They include the absence of a thorough energy policy, disjointed decision-making procedures, lax enforcement and monitoring measures, a lack of strong incentives for private sector investment, and inadequate financing options. A comprehensive strategy that includes the creation of a comprehensive energy policy, improved institutional coordination, strengthened monitoring and enforcement mechanisms, and creation of focused incentives and financing mechanisms is necessary to meet these challenges.

CHAPTER FIVE

DISCRIPTIVE ANALYSIS OF ENERGY ISSUES IN GHANA

5.1. Energy Balance of Ghana

Ghana's reliance on biomass, particularly wood and charcoal, has led to environmental and health concerns. The country is diversifying its energy mix, with oil and gas playing a significant role. This raises questions about sustainability and long-term energy security. Ghana is embracing renewable energy sources like solar and wind to address challenges like energy accessibility, affordability, and environmental concerns. The government is promoting clean energy projects, energy efficiency measures, and modernizing the electricity grid. Ghana's ambitious targets for renewable energy share in the energy mix signal its commitment to a greener, more sustainable future (Nyasapoh et al., 2022).

Table 5.1. Ghana's Energy Balance for the Year 2022

Thousand Tonnes of Oil Equivalent (Ktoe)	Crude Oil	Natural Gas	Petroleum Products	Wood	Charcoal	Solar	Hydro	Waste	Electricity	Total
Production	7325.1	2957.2	0.0	3747.5	0.0	13.9	704.5	0.0	0.0	14748.2
Import (+)	31.5	499.7	4217.2	0.0	0.0	0.0	0.0	0.0	3.2	4751.5
Export (-)	-7269.1	0.0	-11.0	0.0	0.0	0.0	0.0	0.0	-190.5	-7470.5
International Marine Bunkers (-)	0.0	0.0	-2.4	0.0	0.0	0.0	0.0	0.0	0.0	-2.4
International Aviation Bunkers (-)	0.0	0.0	-194.2	0.0	0.0	0.0	0.0	0.0	0.0	-194.2
Stock Changes	66.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.9
Total Energy Supply	154.5	3456.9	4009.5	3747.5	0.0	13.9	704.5	0.0	-187.3	11899.5
Transfers: Origin (-) and Destination (+)	-123.0	0.0	125.8	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Statistical Differences	0.0	37.8	-18.3	7.3	0.0	0.0	0.0	0.0	0.0	26.8
Transformation Inputs (-) and Output (+)	**-31.5**	**-3205.1**	**39.9**	**-1803.9**	**970.3**	**-13.9**	**-704.5**	**0.0**	**1992.0**	**-2756.7**
Electricity Plants	0.0	-3205.1	0.0	0.0	0.0	-13.9	-704.5	0.0	1992.0	-1931.4
Oil Refineries	-31.5	0.0	39.9	0.0	0.0	0.0	0.0	0.0	0.0	8.4
Other Transformation	0.0	0.0	0.0	-1803.9	970.3	0.0	0.0	0.0	0.0	-833.6
Energy Sector Own Use	**0.0**	**0.0**	**50.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**66.6**	**117.1**
Losses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	229.9	229.9
Total Final Consumption	**0.0**	**214.0**	**4143.0**	**1936.4**	**970.3**	**0.0**	**0.0**	**0.0**	**1508.2**	**8771.8**
Residential	0.0	0.0	165.5	1576.0	908.7	0.0	0.0	0.0	610.6	3260.7
Industry	0.0	214.0	514.3	334.6	0.3	0.0	0.0	0.0	638.8	1701.9
Commerce and Service	0.0	0.0	20.8	25.9	61.3	0.0	0.0	0.0	255.0	363.0
Agriculture and Fisheries	0.0	0.0	90.5	0.0	0.0	0.0	0.0	0.0	2.8	93.3
Transport	0.0	0.0	3351.9	0.0	0.0	0.0	0.0	0.0	0.9	3352.8
Non-Energy Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Source: Generated by the author using data National Energy Information Repository (2022))

From the table above, solar energy production was small at 13.89 ktoe, meeting only 0.1% of Ghana's total energy supply. This indicates that solar currently plays a very minor role in Ghana's energy mix. There was no reported final consumption of solar energy. Solar contributes marginally to electricity generation. The minimal solar production and consumption suggests significant potential for growth in solar generation and use in Ghana through investments in solar PV, water heating, and other technologies. Targeting the residential sector could help displace biomass use. (Boamah & Rothfuß, 2018). Petroleum products like gasoline, diesel, kerosene, and LPG made up the largest share of energy imports at 4,217.17 ktoe. Petroleum products accounted for 47% of Ghana's total final energy consumption at 4,142.98 ktoe, second only to biomass. Most petroleum consumption was in the transport sector at 3,351,89 ktoe, meeting nearly all its fuel needs. The residential sector consumed 165.47 ktoe of petroleum products, likely LPG for cooking needs. The table shows petroleum products are critical to Ghana across sectors. Developing domestic refining capacity could lessen the reliance on imports for petroleum fuels. Improving public transport and vehicle efficiency could curb growth in oil demand. Total electricity generation was 1,992.01 ktoe, meeting about 17% of Ghana's overall energy supply. Hydro generation contributed 704 ktoe or 26% of total electricity produced. Imports of electricity were negligible at 3.21 ktoe, while exports were 190 ktoe. Final electricity consumption was 1,508.18 ktoe, going primarily to the residential (610.62 ktoe), industrial (638.79 ktoe) and service (255.03 ktoe) sectors. Expanding generation capacity, especially through natural gas and renewables, could help meet rising electricity demand in Ghana. Reducing transmission losses is also key.

Natural gas production was 2,957.18 ktoe, providing the largest share of energy inputs for electricity. Natural gas imports were a sizable 499.65 ktoe, supplementing domestic supply. 3,205.06 ktoe of natural gas went towards transformation processes, predominantly electricity generation. Final gas consumption was just 213.96 ktoe in the industrial sector. Natural gas is critical for Ghana's electricity production and appears well supplied through domestic production and imports. Further developing gas infrastructure could support electricity demand growth. Hydro electricity generation was 704 ktoe, meeting about 26% of Ghana's total electricity generation in 2022. There were no imports or exports of hydroelectricity reported. The energy balance data indicates hydro provides a significant portion of Ghana's renewable electricity generation. However, capacity is capped based on existing dam infrastructure.

Crude oil production was very high at 7,325.08 ktoe, making up 49% of Ghana's total energy supply. Crude oil exports were even higher at 7,269.05 ktoe, indicating most oil produced in Ghana is exported rather than refined locally. Only 31.50 ktoe of crude oil was input to refineries for domestic petroleum production. According to (Ayo et al., 2021), while Ghana has significant domestic crude oil production, it lacks refining capacity to fully harness this resource for national energy use. Building local refineries could enhance energy security. Reducing crude exports in favor of domestic refining could help meet petroleum product demand locally rather than relying heavily on imports. Charcoal production was 970.26 ktoe, meeting about 11% of Ghana's total energy supply. All charcoal production went towards final consumption, specifically the residential sector (908.68 ktoe) and commercial/service sector (61.32 ktoe). Charcoal is a key energy source for household cooking and small commercial enterprises in Ghana. Managing charcoal production and consumption sustainability will be important given its environmental impacts. Wood production was 3,747.54 ktoe, meeting 31% of Ghana's total energy supply. 1,803.86 ktoe of wood was used for transformation processes, likely for charcoal production and heating and cooking needs. Final wood consumption was 1,936.41 ktoe, going predominantly to the residential sector at 1,575.95 ktoe, 334.57 ktoe to the industry and 25.88 ktoe to the service sector. (Bawakyillenuo et al., 2021) indicates that wood fuels meet a large portion of residential energy demand for heating and cooking in Ghana. Managing forestry resources sustainably will be crucial to maintain supply. Overall, the table suggests waste currently plays a small role in Ghana's energy mix, but quantifying waste streams could help target technologies to recover greater energy value while improving waste management.

5.2. Renewable Energy

The 2011 Ghanaian Parliament passed the Renewable Energy Act (832) with the aim of fostering the development, management, utilization, sustainability, and supply of renewable energy. The legislation encompasses various provisions, such as licensing procedures, feed-in tariff plans, buying obligations, and net metering. Under the feed-in tariff scheme, electricity generated from renewable sources can be sold to the national grid, and the Public Utility Regulatory Commission (PURC) is tasked with establishing the feed-in tariff rates (Ministry of Energy, 2019). Ghana possesses significant potential in diverse renewable energy sources, including hydropower, bioenergy, wind, and solar power. Notably, the country is equipped with three major hydropower stations, including the well-known Akosombo Dam, which contributes 40% of Ghana's total installed electrical capacity.

Although there has been a decline in hydropower's share, there remains significant untapped potential, with over 14 possible hydro sites offering a total power of 740 MW(Kalitsi, 2003). Bioenergy, utilizing resources like cow dung and agricultural waste, presents an opportunity for sustainable fuel production, addressing rural poverty and promoting women's empowerment. The country aims to replace petroleum fuels with biofuels, targeting a 10% consumption by 2020 and 20% by 2030(Arthur et al., 2011). According to (Aboagye et al., 2021),wind energy potential along the eastern coastline and hills around Lake Volta is being explored, with agreements in place for the development of wind parks. Finally, in solar energy as discussed by (Gauri Singh, 2015), Ghana benefits from abundant sunlight, with the first and largest photovoltaic power station in Africa—the Nzema project. The solar sector holds great promise, as evidenced by the ability to provide 100 times the nation's current power needs. With training initiatives and numerous installed solar systems, Ghana is making strides in harnessing its renewable energy potential for sustainable development.

Table 5.2. Total renewable energy capacity in Ghana from 2012 to 2021

Year	Total Renewable Energy Capacity (Megawatts)
2012	1,187
2013	1,590
2014	1,594
2015	1,624
2016	1,630
2017	1,640
2018	1,670
2019	1,677
2020	1,700
2021	1,700

(Source: Generated by the author using data from Statista (2021))

The data shows a consistent growth in total renewable energy capacity from 1,187 MW in 2012 to 1,624 MW in 2015. This suggests a positive trend in the development and adoption of renewable energy sources during this period. After 2015, there is a steady increase in the total renewable energy capacity, reaching 1,700 MW in both 2020 and 2021. This period of stability indicates a sustained effort in maintaining and potentially expanding the renewable energy infrastructure in Ghana. Understanding the proportion of total energy capacity that renewable sources represent in the overall energy mix is crucial. It provides insights into the significance of renewables in meeting the country's energy needs. To sustain and further enhance renewable energy capacity, policymakers and stakeholders may need to continue supporting the sector through policies, investments, and innovations. Apart from that, monitoring global trends and adapting strategies accordingly will be essential. In summary, the data indicates a positive trajectory in the growth of total renewable energy capacity in Ghana from 2012 to 2021, with a recent period of stability. A comprehensive analysis would involve considering external factors and understanding the specific types of renewable energy sources contributing to this capacity.

Table 5.3. Percentage of Electricity Capacity in Ghana Derived from Renewable Sources from 2012 to 2021

Year	Share of Electricity Capacity (%)
2012	49.4
2013	56.6
2014	56.7
2015	57.1
2016	46.2
2017	41.4
2018	40.9
2019	32.3
2020	32.7
2021	31.7

Source: Generated by the author using data from Statista (2021)

The share of renewable energy in electricity capacity in Ghana has shown a general upward trend from 2012 to 2015, reaching a peak at 57.1% in 2015. However, there has been a subsequent decline from 2016 onwards, with the share dropping to 31.7% in 2021. The peak in 2015 at 57.1% indicates a significant achievement in promoting renewable energy capacity during that period. The subsequent decline suggests challenges or changes in the energy landscape that affected the relative contribution of renewable sources. Policy changes, shifts in energy investment, or economic factors may have influenced the decline in the share of renewable energy capacity. Changes in government priorities, fluctuations in energy prices, or challenges in the implementation of renewable energy projects could also be contributing factors. From 2018 to 2021, the decline seems to have stabilized, with the share fluctuating within a relatively narrow range (between 31.7% and 40.9%). It's crucial to consider external factors, such as the overall growth in electricity demand, changes in fossil fuel capacity, and policy interventions, to better understand the dynamics behind these numbers. Policymakers need to review and adjust existing policies to reinvigorate the growth of renewable energy if maintaining or increasing the share of renewables is a priority. Despite the recent decline, there may be opportunities for renewed emphasis on renewable energy, especially given the global focus on sustainable development and the increasing urgency to address climate change. Further investigation into the specific reasons for the decline, such as changes in regulations, funding, or technology costs, would provide a more detailed understanding of the observed trends. In summary, while there was a notable increase in the share of renewable energy in electricity capacity in Ghana until 2015, the subsequent decline calls for a closer examination of the factors influencing this trend. Understanding the context and identifying the reasons behind these changes will be essential for formulating effective strategies to promote sustainable energy development in the future.

5.2.1. Challenges Facing the Renewable Energy Sector of Ghana

The renewable energy sector in Ghana faces a significant technological limitation, with workers lacking the necessary skills for innovation, feasibility assessments, and device operation, leading to a significant gap in identified renewable energy sources. (Mahama et al., 2020) highlight human resistance to new technologies in the renewable energy sector in Ghana, causing slow progress due to slow user feedback and a long time for effective use of identified renewable energy sources. (Ankrah & Lin, 2020) also identified the issue of low public and media awareness about renewable energy resources in Ghana, which hinders their promotion and potential use. The lack of information about these energy forms can lead to fear and uncertainty among the population. (Sakah et al., 2017) indicate that the bureaucratic procedures in obtaining licenses and permits for renewable businesses in Ghana, which can take longer and hinder sector growth, making investors reluctant to invest in such businesses.

5.2.2. Strategies to Mitigate Renewable Energy Challenges in Ghana.

Ghana stands to benefit from the considerable strides made by Morocco in the realm of renewable energy. Drawing inspiration from Morocco's noteworthy achievements, Ghana could formulate a comprehensive national strategy with well-defined objectives and timelines. Emulating Morocco's ambitious renewable energy agenda, which encompasses extensive solar and wind projects, could prove instrumental for Ghana's own sustainable energy development. Morocco's substantial investments in solar energy, exemplified by initiatives like the Noor Solar Complex, one of the world's largest solar power plants, offer a template for Ghana to explore comparable large-scale solar projects, tapping into its abundant sunlight for electricity generation (Okpanachi et al., 2022).

Recognizing the intermittency inherent in renewable energy sources, Morocco has effectively addressed this challenge through the implementation of energy storage solutions. Ghana could study Morocco's approach to energy storage, particularly the utilization of batteries, to bolster the dependability of its own renewable energy systems. Moreover, Morocco's engagement in regional collaborations and partnerships for energy infrastructure development serves as a model for Ghana to consider. Exploring collaborative opportunities with neighboring countries could optimize the regional utilization of renewable resources (Orewa et al., 2023).

Morocco's commitment to capacity building and research in the renewable energy sector provides a further avenue for emulation by Ghana. Prioritizing the development of a skilled workforce and fostering research and development initiatives would be essential for Ghana to advance its capabilities in the realm of renewable energy. In essence, Ghana could leverage Morocco's experience across these multifaceted dimensions for the enhancement of its own renewable energy landscape.

Morocco has enhanced its grid infrastructure to facilitate the seamless integration of renewable energy sources. Ghana, in pursuit of fostering a more extensive incorporation of renewable energy, can prioritize the modernization of its grid. This strategic emphasis on grid modernization would not only support the heightened integration of renewable energy but also contribute to the maintenance of a stable and efficient electricity supply within the country (Moudene et al., 2023).

While learning from Morocco's experiences, Ghana should also consider its unique local context, including geographical conditions, energy demand patterns, and socio-economic factors. Adaptability is crucial to the success of renewable energy initiatives. It's essential for Ghana to assess its specific needs and challenges and tailor its renewable energy strategy accordingly. Regular updates on developments in the renewable energy sector would provide more current insights for any ongoing initiatives in both Ghana and Morocco (Eni & Mattei, 2017).

The government should introduce transparent, targeted subsidies and cash benefits for renewable energy production, as current subsidies do not benefit developers and importers in the free zone market.(Sakah et al., 2017). The proposed net metering scheme should be introduced to ensure grid support and meet family energy needs, promoting universal energy access. Awareness creation is crucial to ensure households are fully aware of the energy type they will receive(Mahama et al., 2020). The Ministry of Energy should establish investment opportunities for renewable energy projects through the Energy Commission. Financial institutions and insurance firms can be trained on project feasibility, increasing confidence in funding and mitigating risks. Government guarantees could motivate banks to lower interest rates (SREP Sub-Committee, 2015).

5.2.3. Policies and Institutional Framework

Throughout the years, the Government of Ghana has enacted policies aimed at fostering the advancement and enhancement of technologies within the renewable energy sector. To operationalize these policies, distinct institutions have been established and entrusted with specific responsibilities in this domain.

Ghana, as a member of the Economic Community of West African States (ECOWAS), subscribes to the organization's energy strategies and legislative frameworks. The ECOWAS renewable energy policy envisions providing unimpeded access to electricity for all residents within the ECOWAS region. As outlined in the White Paper, a minimum of 20% of new investments in electricity production in remote and peri-urban areas should originate from renewable sources. Projections outlined in the document anticipate that renewable energy will constitute approximately 48% of the total installed electricity capacity in the ECOWAS region by the year 2030 (Ministry of Energy, 2019).

An additional factor to consider is the enactment of the Renewable Energy Act of 2011 (Act 832), which aims to establish a conducive regulatory framework to attract private sector involvement in the efficient and environmentally sustainable production, management, and utilization of renewable energy in Ghana. This legislation addresses numerous aspects related to the handling of renewables in the country, including those receiving developmental focus. The roles and responsibilities of various institutions are explicitly delineated within the provisions of this act (Parliament of Ghana, 2020). Adobea Oduro et al. (2020) underscore Ghana's utilization of diverse funding mechanisms for renewable energy projects, such as the Ghana Renewable Energy Risk Capital (GRERC), with a specific emphasis on supporting Small and Medium Enterprises (SMEs) and domestic green initiatives. However, it is important to note that certain projects, such as the Ape Bank Project, have encountered challenges and remain incomplete.

5.3. Carbon dioxide Emissions of Ghana

The emission of carbon dioxide (CO2) stemming from energy consumption has garnered considerable attention, particularly in the context of ongoing climate change (Wesseh & Lin, 2018). Consequently, numerous governments have undertaken various initiatives to curtail CO2 emissions. Examples of substantial endeavors in this regard include the 2015 Paris Climate Change Agreement and the United Nations Sustainable Development Goals (SDGs) (Antwi-Agyei et al., 2018). Just like many other countries, Ghana has also made attempts at fulfilling its contributions to the achievement of policy frameworks in the Paris Climate Change Agreement which is to establish zero carbon dioxide emissions. These attempts have been through the Intended Nationally Determined Contributions (INDCs) which acts as short-term goals with the aim of meeting the targets of the Paris Agreement in the long run. Some of Ghana's INDCs include the promotion of transformation to a more viable power system, improvement of the restoration of the landscape and other activities that will help in the minimization of carbon emissions while still using energy in ways that will promote the country's economic growth (Nationally et al., 2021). Kwakwa et al 2020 unearthed that urban sprawl and natural resource removal from their sources play a part of Ghana's carbon dioxide emissions. A greater part of the population of Ghana has settled in the metropolitan areas of the country. These settlements have led to the exploitation of the various natural resources available through electricity production, transportation activities, agriculture, land use and forestry activities, industry as well as residential activities. According to (Maccarthy et al., 2018) a variety of land-use systems strongly influenced soil carbon dioxide emissions. They added that carbon dioxide emissions were principally caused by the decomposition of organic materials in the soil. The land-use practices that regularly disturb and expose the organic matter in the soil to decomposition and mineralization are most likely to release more greenhouse gases (GHGs).

Table 5.4. Ghana's Carbon Emissions by Sector from 2012 to 2019 (Million Tonnes)

Sector	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**
Agriculture	10.24	10.14	10.41	9.95	9.84	9.36	9.54	8.81
Transport	8.75	8.28	7.28	7.51	8.12	7.49	7.44	7.03
Electricity and Heat	5.96	5.29	4.64	4.27	3.37	3.32	3.69	3.1
Waste	3.73	3.64	3.56	3.47	3.38	3.3	3.22	3.14
Industry	2.9	2.79	2.61	2.59	2.42	2.59	2.51	2.43
Manufacturing and Construction	2.5	2.3	2.03	1.72	1.83	1.69	1.77	1.70
Buildings	1.61	1.54	1.54	1.42	1.41	1.32	1.36	1.45
Fugitive Emissions	1.58	1.45	1.72	940,000	990,000	840,000	710,000	490,000
Aviation and Shipping	890,000	670,000	820,000	420,000	390,000	410,000	590,000	710,000
Other fuel Combustion	390,000	390,000	410,000	230,000	250,000	230,000	370,000	380,000
Land-use change and forestry	24.9	24.89	24.9	24.85	29.42	29.41	29.42	29.43

Source: Generated by the author using data from Our World in Data (2021)

Land use change and forestry emissions are the largest mediums of carbon emissions in Ghana, releasing 25 million tonnes annually from 2012 to 2019. The lack of reduction in emissions raises concerns about the effectiveness of current deforestation limitation efforts, posing environmental threats and climate change. Agriculture is the second-largest contributor to Ghana's greenhouse gas emissions, with annual fluctuations ranging from 8.8 to 10.4 million tonnes. The absence of a clear reduction trend suggests significant changes in agricultural practices. To address emissions, transitioning to sustainable land use, adopting climate-smart agriculture, and investing in technology and training are recommended. Transport is the third-largest contributor to Ghana's carbon emissions, with emissions increasing from 7.03 million tonnes in 2012 to 8.75 million tonnes in 2019. Key sources include road vehicles, maritime shipping, and air travel. To limit emissions, Ghana needs policies focusing on public transit, vehicle efficiency standards, electric vehicle incentives, and rail infrastructure investment. Sustainable mobility policies and clean technologies are crucial for addressing this issue.

Electricity and heat are of the sources of emissions in Ghana, increasing from 3.1 million tonnes in 2012 to 5.96 million tonnes in 2019. The growth is attributed to increased electricity generation and consumption, with fossil fuels driving emissions. Investing in renewables and improving energy efficiency will help solve this problem. Ghana's waste sector emissions have slightly increased from 3.14 million tonnes in 2012 to 3.73 million tonnes in 2019, with methane from landfill disposal being a significant contributor. (Amoatey et al., 2023) suggests enhancing solid waste collection, separation, recycling, and treatment to minimize landfilling and capturing landfill methane for energy use. Ghana's industry sector emissions have increased from 2.43 million tonnes in 2012 to 2.9 million tonnes in 2019, with a slight trend of 0.5 million tonnes. Despite growth driven by development, the sector is not among the top-largest emitters. Reducing emissions intensity through cleaner production methods, energy efficiency measures, and transitioning to lower carbon fuels can help sustain industrial development. Ghana's manufacturing and construction sector emissions have increased from 1.7 million tonnes in 2012 to 2.5 million tonnes in 2019, primarily due to economic development and expansion. Key industries contributing to increased emissions include food processing, textiles, chemicals, cement, and construction. Mitigation strategies include improving energy efficiency, transitioning to renewable energy, adopting cleaner production methods, and implementing waste minimization and recycling practices. Ghana's buildings sector emissions have fluctuated from 1.45 million tonnes in 2012 to 1.61 million tonnes in 2019, driven by energy use for lighting, air conditioning, and appliances. Higher standards for building energy efficiency and incentives for rooftop solar systems and LED lighting can help manage greenhouse gas outputs.

Fugitive emissions in Ghana have fluctuated from 490,000 tonnes in 2012 to 1.58 million tonnes in 2019, driven by variations in oil/gas production activities and system leaks. Despite being a minor source, fugitive emissions have limited impact on Ghana's carbon footprint.

Table 5.5. Annual Carbon dioxide Emission in Ghana from 2012 to 2021

Year	Annual Carbon Emissions (Mt CO2e)
2012	14.38
2013	14.34
2014	14.98
2015	16.03
2016	15.56
2017	13.94
2018	17.10
2019	18.71
2020	19.65
2021	21.31

Source: Generated by the author using data from Our World in Data (2021)

Data on Ghana's annual carbon dioxide (CO2) emissions from 2012 to 2021 show observable patterns and trends that shed light on the environmental impact and potential climate change contributions of the nation. Mt CO2e, or million tonnes of CO2 equivalent, is used to express the values. The values are expressed in million tonnes of CO2 equivalent (Mt CO2e). Ghana's annual CO2 emissions increased noticeably between 2012 and 2015, going from 14.38 million tonnes in 2012 to 16.03 million tonnes in 2015. This spike in emissions may be related to increased energy use, industrial activity, or other anthropogenic factors that contribute to greenhouse gas emissions. Then, in 2016, there was a slight decline to 15.56 million tonnes, which may have been caused by changes in energy consumption patterns or potential fluctuations in economic activity. With a total of 13.94 million tonnes, 2017 saw a significant decrease in CO2 emissions. This decrease could be attributed to several things, including increased energy efficiency, modifications to business practices, or the implementation of environmental regulations. But after this decrease, there was a sharp rise in 2018, reaching 17.10 million tonnes. From 2019 to 2021, annual CO2 emissions show a consistent upward trend, reaching a peak of 21.31 million tonnes in 2021.

This upward trend highlights the difficulties in separating economic growth from carbon emissions and is a sign of sustained economic growth and energy demand. Several factors may account for these trends in Ghana's annual CO2 emissions. Economic growth, urbanization, and increased industrialization are typically associated with rising carbon emissions. The energy mix of Ghana, particularly the reliance on fossil fuels as opposed to renewable sources is essential for figuring out Ghana's energy consumption's carbon intensity. The analysis of Ghana's annual CO2 emissions highlights the complex relationship between economic activities and environmental impact, necessitating effective policies and targeted interventions for sustainable growth.

Table 5.6. Annual Carbon dioxide Emission in Ivory Coast from 2012 to 2021

Year	Annual Carbon Emissions (Mt CO2e)
2012	8.54
2013	9.68
2014	9.90
2015	9.55
2016	11.98
2017	12.00
2018	10.35
2019	10.54
2020	10.96
2021	11.71

Source: Generated by the author using data from Our World in Data (2021)

In 2012, Ghana's carbon emissions stood at 14.38 million tonnes, nearly double the emissions of Ivory Coast, which recorded 8.54 million tonnes. Throughout the subsequent years, both countries exhibited varying trajectories in their carbon emissions. Ghana experienced a generally ascending trend, reaching 21.31 million tonnes in 2021. In contrast, Ivory Coast's emissions fluctuated within a relatively narrower range, reaching 11.71 million tonnes in 2021. One prominent distinction is the magnitude of emissions, with Ghana consistently emitting a substantially higher volume of CO2 compared to Ivory Coast. Ghana's emissions, which surpassed 21 million tonnes in 2021, are approximately twice as much as Ivory Coast's emissions for the same year.

Ghana displayed a more erratic pattern, with noticeable peaks and troughs, indicative of potential fluctuations in economic activities, industrial output, or energy consumption. In contrast, Ivory Coast's emissions, while experiencing some variability, generally maintained a steadier trajectory. The observed disparities may be attributed to variations in economic structures, industrialization levels, and energy profiles between the two countries. Ghana's higher emissions is linked to a more carbon-intensive energy mix, increased industrialization, and a larger population. Economic activities such as mining and agriculture could contribute significantly to Ghana's emissions.

While both nations face challenges related to carbon emissions and their environmental consequences, the data underscores the importance of strategies to address these challenges. Regulations that support the use of clean energy, energy efficiency, and environmentally friendly industrial processes are crucial for mitigating the environmental impact associated with carbon emissions in both Ghana and Ivory Coast. In conclusion, the two sets of data show that while both Ghana and Ivory Coast grapple with carbon emissions, Ghana demonstrates a higher and more fluctuating emissions profile compared to the more stable emissions trajectory observed in Ivory Coast. This comparison provides valuable insights for policymakers in crafting tailored strategies to address carbon emissions within the unique socio-economic and environmental contexts of each nation.

Table 5.7. Global Share of Carbon Emissions by Ghana from 2012 to 2021

Year	Percentage of Emissions (%)
2012	0.04
2013	0.04
2014	0.04
2015	0.05
2016	0.04
2017	0.04
2018	0.05
2019	0.05
2020	0.06
2021	0.06

Source: Generated by the author using data from Our World in Data (2021)

From 2012 to 2017, Ghana's percentage of global carbon emissions remained relatively stable at 0.04%. There is a slight increase in Ghana's global share of carbon emissions from 0.04% to 0.06% from 2018 to 2021. While the change is modest, it indicates a small upward trend in the country's contribution to global emissions during this period. Throughout the entire period (2012-2021), Ghana's percentage of global carbon emissions is quite low, never exceeding 0.06%. This indicates that, in comparison to larger emitting countries, Ghana's carbon emissions on a global scale are minimal. The slight increase in the global share of carbon emissions from 2018 to 2021 could be attributed to various factors such as increased industrial activities, energy consumption, or changes in land use patterns.

While the percentage increase is small, it's important to consider the absolute values of emissions and the country's overall contribution in the context of global emissions. Ghana's relatively low percentage suggests that the country is not a major contributor to the global carbon footprint. Even with a low global share, monitoring and addressing carbon emissions are crucial for sustainable development. Ghana may still focus on mitigation strategies and sustainable practices to limit the growth of emissions and contribute to global efforts to combat climate change. In summary, Ghana's global share of carbon emissions has been consistently low, with a slight increase in recent years. While the country's contribution is relatively small on a global scale, continuous efforts to monitor and mitigate emissions are essential for sustainable development and addressing climate change concerns.

5.3.1. Strategies to Mitigate Carbon Emissions in Ghana

Ghana has established a national strategy for mitigating emissions resulting from deforestation and forest degradation, commonly known as REDD+. This initiative is embedded within the broader national strategy for emissions reduction, as of October 5, 2023 (TWB). However, it is noteworthy that Ghana lacks a long-term decarbonization target or strategy, with its current low-carbon development focus extending only until 2030, as outlined by the Ministry of Environment (Science, 2021). The institutional framework supporting climate mitigation and adaptation in Ghana involves key entities such as the Environmental Protection Agency (EPA), the Forestry Commission, and the Cocoa Board. Despite this, there is a recognized imperative to enhance existing coordination mechanisms to ensure the integration of climate mitigation measures across all relevant ministries and local governments, according to the report dated October 5, 2023, from TWB.

Ghana has entered into a significant agreement with the World Bank aimed at mitigating carbon emissions and diminishing deforestation. The Forest Carbon Partnership Facility (FCPF) has provided financial compensation to Ghana for its initial achievement in reducing carbon emissions during the inaugural monitoring period within the program, as reported on October 6, 2023 (TWB). It is essential to note that Ghana's endeavors in emission reduction are intricately linked to its national strategy for diminishing emissions resulting from deforestation and forest degradation, commonly known as REDD+ (TWB, 06 October 2023). Ghana has developed a Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC), which provides information on the nation's carbon dioxide emissions and mitigation efforts (United Nations et al., 2015). However, there is a need to construct an environmentally friendly regulations that incorporates emission reduction targets and covers all economic sectors is required. (Ministry of Environment, Science, 2021).

Ghana can learn several insights from the European Union Emissions Trading System (EU ETS) in promoting carbon pricing and decreasing carbon dioxide emissions. Ghana can learn from the EU ETS's cap-and-trade system, which guarantees a credible and binding reduction of emissions within the cap (Herman et al., 2020). A cap-and-trade system can help Ghana reduce its greenhouse gas emissions by placing a limit on the total quantity of specific environmental pollutant that are permitted to be released by liable entities. Ghana can learn from the EU ETS's approach to carbon pricing (Tietenberg & States, n.d.). Carbon pricing can help Ghana reduce its greenhouse gas emissions by putting a price on carbon and creating an incentive for companies to reduce their emissions. Ghana can learn from the EU ETS's experience in promoting the carbon market through effective PPP (Herman et al., 2020). PPP can help attract private investment and expertise to the carbon market, which can aid in quickening the adoption of technology for renewable energy. Ghana can learn from the EU ETS's creation of an enabling environment for carbon pricing and carbon trading. Ghana can provide incentives such as feed-in tariffs and tax exemptions for renewable energy projects to promote renewable energy investment. Ghana can learn from the EU ETS's multidisciplinary approach to carbon pricing and carbon trading(Tietenberg & States, n.d.). To encourage carbon pricing and lower greenhouse gas emissions, a multidisciplinary approach is necessary because the traditional boundaries between energy, finance, corporate governance, and the environment are eroding. Overall, Ghana can learn from the EU ETS's experience in promoting carbon pricing and reducing greenhouse gas emissions and develop a sustainable and resilient energy system that meets its energy needs while reducing its dependence on imported fossil fuels.

5.4. Energy Poverty of Ghana

As outlined by Che et al. (2021), energy poverty refers to the lack of access to modern energy services, including electricity and clean cooking facilities, which are essential for meeting basic human needs. This intricate issue holds global significance, particularly affecting populations in low- and middle-income countries. Addressing this challenge effectively necessitates a thorough and reliable evaluation of energy poverty. A commonly employed method for assessing energy poverty is the Multidimensional Energy Poverty Index (MEPI), developed by the United Nations Development Programme (UNDP), as detailed by Halkos and Aslanidis (2023).

The Multidimensional Energy Poverty Index (MEPI) encompasses three fundamental dimensions of energy poverty: access, affordability, and reliability. The evaluation of access involves determining the proportion of the population with access to essential resources such as electricity and clean cooking facilities. Affordability is assessed by calculating the percentage of household income allocated to energy-related expenses. Meanwhile, reliability refers to the frequency and duration of disruptions in energy supply experienced by households. By integrating these three dimensions, the MEPI offers a comprehensive measure for assessing energy poverty, encompassing a variety of factors influencing energy access, as expounded by Halkos and Aslanidis (2023).

According to ISAZADE & ALTAN (2023), an additional frequently employed metric for gauging energy poverty is the count of individuals lacking access to electricity. The International Energy Agency (IEA) approximates that approximately 770 million people worldwide lack electricity access, with a predominant concentration in sub-Saharan Africa and South Asia. This metric offers a fundamental gauge of energy poverty, given that electricity serves as a pivotal facilitator for diverse activities such as illumination, communication, and productive applications. However, it presents limitations as it does not encompass the entire spectrum of energy poverty, neglecting considerations such as access to clean cooking facilities or other contemporary energy services. The overall assessment of energy poverty is a intricate undertaking requiring a multidimensional approach. Global metrics like the MEPI, the count of individuals without electricity access, and the Global Tracking Framework offer valuable insights into the scope and characteristics of global energy poverty. Nevertheless, it is imperative to supplement these metrics with nation-specific measures to capture the intricacies of energy poverty in varied contexts. Utilizing these measurement tools and indicators, policymakers can discern areas necessitating improvement and formulate targeted interventions to effectively address energy poverty, as highlighted by Siksnelyte-Butkiene et al. (2021).

Ghana measures energy poverty using multidimensional measures, including the Multidimensional Energy Poverty Index (MEPI) (Adusah-poku & Takeuchi, 2019a). The MEPI assesses energy poverty based on 13 indicators classified into three energy dimensions: affordability, accessibility, and reliability (Koomson & Danquah, 2021a). Additionally, Ghana uses an income-based measure of energy poverty, which considers households that spend over 10% of their income on energy services as energy-deprived (Lin & Okyere, 2020). Some studies in Ghana have also examined the link between financial inclusion and energy poverty, as well as the impact of energy poverty on household health expenditures(Koomson & Danquah, 2021a). Overall, Ghana's approach to measuring energy poverty is multidimensional and considers various aspects of access, affordability, and reliability of energy services, as well as their impact on households' well-being.

The Multidimensional Energy Poverty Index (MEPI) serves as a tool in Ghana for the evaluation of energy poverty. Developed by Lin and Okyere (2020), the MEPI comprehensively gauges a household's deficiency in contemporary energy access, affordability, and reliability.

Comprising 13 indicators categorized into three energy dimensions—affordability, accessibility, and reliability, as articulated by Adusah-Poku et al. (2021)—the MEPI is employed to calculate the intensity, incidence, and prevalence of energy poverty within Ghana. Lin and Okyere (2020) note a reduction in MEPI across all ten regions of Ghana over the studied period; however, a persistent high prevalence is observed in the three Northern regions.

The application of the Multidimensional Energy Poverty Index (MEPI) extends to evaluating the determinants and drivers of multidimensional energy poverty in Ghana, as evidenced by Adusah-Poku et al. (2021). Furthermore, the MEPI serves as a tool for investigating the correlation between energy poverty and household health expenditures, a perspective explored by Bukari et al. (2021). Policymakers find the MEPI invaluable in strategically identifying regions with elevated instances of energy poverty and formulating policies aimed at alleviating this concern in Ghana, as emphasized by Ahmed and Gasparatos (2020).

5.4.1. Causes and Strategies to Eradicate Energy Poverty in Ghana

Eni & Mattei (2017) indicates that one of the primary causes of Ghana's energy poverty is the limited availability and unreliability of the national electricity grid. Most of the population in rural areas have little to no access to grid electricity, relying instead on alternative sources such as kerosene lamps, candles, or traditional biomass fuels like wood and charcoal for their energy needs. The high cost of electricity tariffs makes it challenging for low-income households to afford regular access to electricity, even when it is available. Furthermore, the lack of awareness and knowledge about alternative energy technologies and their benefits poses further obstacles to widespread adoption. This not only limits their productivity but also poses health risks due to indoor air pollution and the risk of accidental fires. The high cost of electricity is another contributing factor to energy poverty in Ghana. The current tariffs for electricity are relatively high compared to the average income of the population, making it unaffordable for many Ghanaians, especially those living in poverty. Apart from that, the cost of expanding and maintaining the electricity grid infrastructure to reach remote areas is extensive, making it economically challenging for the government or private sector to invest in expanding the grid to these marginalized communities (Arthur et al., 2020).

Despite notable strides in extending electricity access in Ghana, numerous households still lack access to contemporary energy services, constituting a significant aspect of energy poverty (Adusah-poku & Takeuchi, 2019b). Notably, a substantial urban-rural disparity in energy poverty exists, with rural areas experiencing nearly double the energy poverty rate of urban areas, as indicated by Koomson & Danquah (2021b). The overarching factors contributing to energy poverty in Ghana encompass a reliance on traditional biomass, limited access to modern energy services, rural-urban disparities, affordability issues, and deficient implementation frameworks. Addressing this multifaceted set of factors is imperative for mitigating energy poverty in Ghana. An additional noteworthy dimension of Ghana's energy poverty is the prevalent dependence on traditional cooking fuels such as wood and charcoal, particularly in rural settings. The inadequacies in implementing the LPG program, designed to promote cleaner cooking fuel use, are identified by Lin & Okyere (2020) as a significant contributor to energy poverty in Ghana. The suboptimal execution of the LPG program not only has environmental repercussions, contributing to deforestation and ecosystem degradation, but also imposes adverse effects on the well-being and livelihoods of women and children. This is particularly significant as women and children are typically responsible for cooking in Ghanaian households, as expounded by Bawakyillenuo et al. (2021).

In recent times, the Ghanaian government has undertaken initiatives to combat energy poverty, with the Rural Electrification Program standing out as a notable effort. This program is designed to extend grid electricity to remote communities, enhancing access to clean and dependable energy sources. Substantial progress has been achieved in augmenting electricity access through this initiative, and it is anticipated that approximately 85% of Ghana's population will be connected to the electricity grid by 2025, according to Adusah-Poku & Takeuchi (2019). Concurrently, the government has enacted policies to encourage the adoption of renewable energy sources like solar and wind power, aimed at diversifying the energy matrix and diminishing dependence on fossil fuels. Despite these endeavors, challenges persist in realizing universal energy access in Ghana, with the financial constraints associated with sustaining and expanding the electricity grid infrastructure, particularly in remote regions, constituting a noteworthy impediment.

In conclusion, Ghana's energy poverty is a complex issue that requires a multi-faceted approach for effective resolution. Improved electricity infrastructure, increased access to affordable and clean energy sources, as well as education and awareness programs, are essential components of addressing this challenge. Through continued efforts and investments, Ghana has the potential to overcome energy poverty and improve the lives of its citizens, thereby contributing to sustainable development and economic growth.

Table 5.8. Energy Access of Ghana from 2012 to 2021

Year	Percentage of Access
2012	56.51
2013	70.70
2014	78.30
2015	74.08
2016	79.30
2017	79.00
2018	80.40
2019	83.50
2020	85.87
2021	86.30

Source: Generated by the author using data from Our World in Data (2021)

The data illustrates a gradual amelioration in energy accessibility within Ghana across the years. The proportion of the population endowed with access to contemporary energy services has consistently risen from 43.70% in 2000 to 85.87% in 2020. This positive trajectory signifies advancements in mitigating energy poverty, reflecting an increased prevalence of electricity access and enhanced cooking facilities. While an overall positive trend is discernible, intermittent fluctuations are observed in the dataset. Noteworthy instances include a substantial decline in energy access from 2005 (41.25%) to 2006 (55.09%) and another decrease in 2012 (56.51%). These oscillations may be attributed to diverse factors, encompassing alterations in energy policies, economic conditions, or infrastructural development.

The years from 2010 to 2020 saw accelerated growth in energy access, with the percentage of the population with access increasing from 64.20% to 85.87%. This could be indicative of targeted efforts to address energy poverty during this period. While the data provides a national overview, it's important to note that energy poverty can vary significantly by region within a country. Some areas may have higher energy access rates than others, and addressing regional disparities should be a consideration in energy poverty alleviation efforts. Ghana has made significant strides in improving energy access over the years, which is a positive sign in the fight against energy poverty. However, it's essential to continue monitoring and analyzing the data to ensure that energy access is sustainable, equitable, and contributes to overall development and poverty reduction in the country.

Table 5.9. Ghana's Electricity Prices from 2012 to 2021 (Ghanaian Cedi per Kilowatt Hour)

Year	Electricity Price (GHC /kwh)
2012	0.23
2013	0.31
2014	0.46
2015	0.54
2016	0.82
2017	0.80
2018	0.71
2019	0.72
2020	0.75
2021	0.75

Source: Generated by the author using data from Statista (2021)

The data shows fluctuations in electricity prices over the years. In 2012, the electricity price was relatively low at $0.23 per kilowatt-hour (kWh). There was a notable increase in 2013, followed by further fluctuations in subsequent years. Understanding the reasons behind these fluctuations is crucial for assessing their impact on energy poverty. The increase in electricity prices, especially from 2012 to 2016, may have implications for the affordability of electricity for households. Higher prices can pose challenges for low-income households, potentially contributing to energy poverty. It's important to consider the relationship between electricity prices and the income levels of the population. After the peak in 2016, there seems to be a degree of stabilization in electricity prices. From 2018 to 2021, the prices hover around $0.71 to $0.75 per kWh. This relative stability may provide some predictability for consumers and businesses, but the affordability aspect remains a concern if these prices are high relative to income levels.

Analyzing electricity prices in conjunction with energy access data can provide a more comprehensive picture. It's important to assess whether the increase or stability in prices aligns with improvements in energy access and whether the population can afford the electricity provided. The data on electricity prices per kilowatt-hour and energy access in Ghana from 2012 to 2021 provides valuable insights into the dynamics of energy poverty in the country. In terms of electricity prices, there is a discernible upward trend over the period, from 0.23 in 2012 to a steady 0.75 in 2020 and 2021. This trend reflects an increase in the cost of electricity over the years, potentially posing a financial burden on consumers. On the other hand, the data on energy access reveals a consistent improvement in the percentage of the population with access to electricity. The percentage of access has grown from 56.51% in 2012 to 86.30% in 2021.

This indicates commendable progress in expanding electricity availability to a larger portion of the population.

However, the simultaneous increase in electricity prices suggests a potential challenge in mitigating energy poverty, as the cost of electricity has become relatively higher, especially for those on lower income levels. The disparity between the rising electricity prices and improving energy access underscores the complex nature of addressing energy poverty. Policymakers may need to implement measures to ensure that the benefits of increased energy access are not overshadowed by the economic strain caused by escalating electricity prices. Additionally, further analysis is warranted to explore the factors influencing the divergent trends in electricity prices and energy access, with a focus on achieving a balance that promotes both affordability and inclusivity in energy provision. In conclusion, while Ghana has made notable progress in expanding energy access, the concurrent rise in electricity prices underscores the intricate balance required to address energy poverty effectively. Policymakers need to carefully navigate the interplay between affordability and accessibility, considering factors such as economic conditions and technological advancements. A comprehensive strategy that addresses both the cost and availability of electricity is crucial for ensuring sustainable progress in alleviating energy poverty in Ghana.

Table 5.10. Ghana’s Total Energy Consumption from 2012 to 2021

Year	Total Energy Consumed (Ktoe)
2012	8,829
2013	8,884
2014	9,018
2015	9,390
2016	9,443
2017	9,361
2018	10,600
2019	11,186
2020	12, 013
2021	12,262

Source: Generated by the author using data from Statista (2021)

The data on Ghana's total energy consumption from 2012 to 2021 presents a comprehensive view of the country's energy dynamics and its potential implications for energy poverty. The total energy consumed, measured in kilotonnes of oil equivalent (Ktoe), exhibits a discernible upward trend over the analyzed period. Beginning at 8,829 Ktoe in 2012, the total energy consumption has steadily increased, reaching 12,262 Ktoe in 2021. The relationship between total energy consumption and energy poverty is intricate. On one hand, an increase in energy consumption can be indicative of economic growth, industrial development, and an improving standard of living. However, if this heightened energy demand outpaces the expansion of energy infrastructure or is met with challenges in affordability, it could contribute to energy poverty, especially for lower-income households. Several factors may account for the observed increase in total energy consumption in Ghana. Economic growth, urbanization, and population expansion are primary drivers of heightened energy demand.

As industries burgeon and urban areas expand, the need for electricity and other forms of energy intensifies. Additionally, improvements in living standards and increased reliance on electronic devices and appliances contribute to the overall surge in energy consumption. The role of government policies and investments in energy infrastructure is pivotal in understanding the dynamics of energy consumption. Support for renewable energy projects, expansion of the electricity grid, and initiatives to enhance energy efficiency can mitigate the adverse effects of rising energy consumption on energy poverty. However, it is imperative to assess whether the growth in energy consumption aligns with the accessibility and affordability of energy services. Disparities in energy access between urban and rural areas, as well as income inequalities, could exacerbate energy poverty concerns. Policies that prioritize inclusive and sustainable energy development are essential to ensure that the benefits of increased energy consumption are distributed equitably. In conclusion, while the rise in Ghana's total energy consumption may signify positive economic development, it necessitates careful consideration of its impact on energy poverty. A holistic approach involving sustainable energy policies, infrastructure investments, and strategies to address socio-economic disparities is crucial to ensure that the benefits of increased energy consumption contribute to the overall well-being of the population without exacerbating energy poverty challenges.

RECOMMENDATIONS

The study highlights the following recommendations for policy and future research:

Recommendations for Policy and Practice:

1. Diversify Ghana's energy mix: The research recommends the imperative for Ghana to diversify its energy portfolio for the attainment of a sustainable energy future. It is advised that the government give precedence to the advancement of renewable energy sources, including solar, wind, and hydropower. Simultaneously, an exploration into the potential of energy storage technologies is advocated. Furthermore, the government is urged to actively promote energy efficiency measures aimed at diminishing both energy consumption and associated costs.

2. Increase investment in renewable energy: The government is advised to augment its financial commitment to renewable energy projects as a means to bolster energy security and diminish reliance on fossil fuels. Additionally, it is recommended that the government institute incentives to encourage private sector investment in renewable energy initiatives, including measures such as tax incentives and subsidies.

3. Improve access to energy in rural areas: This indicates a necessity for the government to give precedence to the establishment of off-grid renewable energy initiatives, such as solar home systems and mini-grids, with the aim of enhancing energy accessibility in these regions. Moreover, it is advisable for the government to extend financial and technical assistance to local communities for the initiation and upkeep of these projects.

4. Strengthen the legal and policy framework: The study identifies problems with the legal and policy framework related to energy and the environment in Ghana. The government should strengthen the legal and policy framework to promote sustainable energy development and protect the environment. This could include updating existing policies and regulations, as well as developing new ones to address emerging issues.

5. Promote public-private partnerships: The study also highlights the potential for public-private partnerships (PPPs) to promote investment in renewable energy projects and improve energy access in Ghana. The government should promote PPPs in the energy sector by providing a supportive legal and regulatory framework, as well as financial and technical support to private sector partners.

6. Increase public awareness and participation: The investigation underscores the significance of fostering public awareness and involvement in advancing sustainable energy

development in Ghana. It is recommended that the government initiate public awareness campaigns to enlighten citizens on the advantages of renewable energy and energy efficiency measures. Furthermore, there is a call for governmental encouragement of public engagement in energy-related decision-making processes, incorporating practices like public consultations and stakeholder involvement.

7. Address energy poverty: The study underscores the prevalent challenge of energy poverty in Ghana, notably within low-income households. It is recommended that the government formulate focused social initiatives to combat energy poverty, incorporating measures such as subsidies for low-income households to avail themselves of clean energy technologies. Additionally, there is an advocacy for governmental prioritization of renewable energy projects in economically disadvantaged areas, aiming to enhance energy accessibility and alleviate energy expenses for households in these regions.

8. Monitor and evaluate energy policies and programs: The study emphasizes the importance of monitoring and evaluating energy policies and programs to ensure their effectiveness and identify areas for improvement. The government should establish a monitoring and evaluation framework to track the progress of energy policies and programs, as well as conduct regular evaluations to assess their impact on energy security, affordability, and environmental sustainability.

Recommendations for Further Research

1. Examine the viability of renewable energy sources in Ghana: The investigation underscores the imperative for Ghana to broaden its energy portfolio and augment investments in renewable energy. Subsequent research endeavors should delve into the potential of renewable sources like solar, wind, and hydropower within the Ghanaian context. This inquiry may encompass an in-depth examination of the technical and economic viability of proposed renewable energy projects, along with a thorough evaluation of their environmental and social repercussions.

2. Analyze the impact of energy subsidies on the Ghanaian economy: The research briefly touches on the issue of energy costs and affordability in Ghana. Further research could explore the impact of energy subsidies on the Ghanaian economy, including an analysis of the costs and benefits of these subsidies. This research could also investigate alternative policies to promote energy affordability, such as energy efficiency measures and targeted social programs.

3. Assess the effectiveness of Ghana's energy policy: The study provides an overview of Ghana's energy policy, but further research could assess the effectiveness of this policy in achieving its goals. This research could include an analysis of the policy's impact on energy

security, affordability, and environmental sustainability, as well as an assessment of the policy's implementation and enforcement.

4. Investigate the potential for public-private partnerships in the Ghanaian energy sector: The research discusses the role of public-private partnerships (PPPs) in the Ghanaian energy sector. Further research could investigate the potential for PPPs to encourage funding for renewable energy initiatives and improve access to energy in Ghana. This research could include an analysis of successful PPP models in other countries and an assessment of the legal and administrative structure for PPPs in Ghana.

5. Analyze the impact of energy use on public health in Ghana: The study discusses briefly how energy use affects the environment, but further research could investigate the energy use's effects on public health in Ghana. This research could include an analysis of air pollution's effects on health and other environmental impacts of energy use, as well as an assessment of the economic costs of these health impacts. This research could also investigate policies and programs to promote clean energy and improve public health in Ghana.

6. Investigate the potential for energy storage technologies in Ghana: The study briefly mentions the issue of energy access in Ghana, but further research could investigate the potential for energy storage technologies to improve energy access in remote and rural areas. This research could include an analysis of the technical and economic feasibility of energy storage projects, as well as an evaluation of the project's effects on society and the environment.

CONCLUSION

This research explored the relationship between energy consumption, economic growth, and environmental impacts in Ghana. The analysis of energy indicators revealed rising energy demand and greenhouse gas emissions over the past decade, posing sustainability challenges. Traditional biomass remains heavily utilized for cooking and heating needs, contributing to indoor air pollution and deforestation. While electricity access has expanded, high tariffs and intermittent supply adversely impact households and businesses. Fossil fuels dominate Ghana's energy mix, but untapped renewable potential exists. Legal and policy frameworks lack cohesiveness in addressing energy and environmental issues. Key recommendations include diversifying the energy portfolio through increased investments in renewable sources like solar, wind and hydroelectric power. Promoting alternatives to traditional biomass and expanding clean cooking programs can mitigate pollution and forest degradation. Energy efficiency strategies for buildings, industry and transport can curb energy intensity. Targeted financing and subsidies are needed to facilitate clean energy adoption by low-income groups. Stronger legal frameworks, comprehensive energy policies and enhanced institutional coordination can address existing gaps. In conclusion, Ghana faces complex energy issues at the intersection of economic, social, and environmental dimensions. An integrated policy approach tailored to local contexts is essential for transitioning towards an optimal energy system. Success factors encompass political commitment, private sector collaboration, social inclusiveness, and ecological stewardship. With appropriate strategies, Ghana can achieve the interlinked goals of energy security, affordability, and sustainability. This study aimed to provide useful insights into Ghana's energy landscape to inform policy and decision-making. Further research and persistent, multi-stakeholder efforts are vital to fully comprehend and tackle Ghana's intricate energy challenges.

BIBLIOGRAPHY

Ablo, A. D., & Asamoah, V. K. (2018). Local participation, institutions and land acquisition for energy infrastructure: The case of the Atuabo gas project in Ghana. *Energy Research and Social Science*, *41*(June 2017), 191–198. https://doi.org/10.1016/j.erss.2018.03.022

Aboagye, B., Gyamfi, S., Ofosu, E. A., & Djordjevic, S. (2021). Status of renewable energy resources for electricity supply in Ghana. In *Scientific African* (Vol. 11). Elsevier B.V. https://doi.org/10.1016/j.sciaf.2020.e00660

Aboagye, S. (2017). *Economic Expansion and Environmental Sustainability Nexus in Ghana*. *29*(2), 155–168.

Aboagye, S. (2019). Is Energy Consumption Responsible for Environmental Degradation in Ghana? *Journal of Applied Economics and Business Research*, *9*(1), 38–50.

Ackah, I., & Asomani, M. (2015). Empirical analysis of renewable energy demand in ghana with autometrics. *International Journal of Energy Economics and Policy*, *5*(3), 754–758.

ACTC, African Climate Technology Centre. "Ghana - Energy Efficiency in buildings". 26, May 2023. https://www.african-ctc.net/our-activities/projects/mitigation/ghana-energy-efficiency-in-buildings/

Adjei Sowa, D. M. (2019). Rapid oil spill simulation within Ghana's coastal waters. *E3S Web of Conferences*, *96*(201 9). https://doi.org/10.1051/e3sconf/20199603002

Adu-gyamfi, S. (2020). *History of technology*. *10*(1), 10–33. https://doi.org/10.32703/2415-7422-2020-10-1(16)-10-33

Adusah-Poku, F., Adjei-Mantey, K., & Kwakwa, P. A. (2021). Are energy-poor households also poor? Evidence from Ghana. *Poverty and Public Policy*, *13*(1), 32–58. https://doi.org/10.1002/pop4.301

Adusah-poku, F., & Takeuchi, K. (2019a). *Energy poverty in Ghana : Any progress so far ?* *112*(July 2018), 853–864. https://doi.org/10.1016/j.rser.2019.06.038

Adusah-Poku, F., & Takeuchi, K. (2019). Determinants and welfare impacts of rural electrification in Ghana. *Energy for Sustainable Development*, *52*, 52–62. https://doi.org/10.1016/j.esd.2019.07.004

Adusah-Poku, F., Dramani, J. B., & Adjei-Mantey, K. (2022). Determinants of electricity demand in Ghana: the role of power crises. *International Journal of Sustainable Energy*, *41*(6), 699–712. https://doi.org/10.1080/14786451.2021.1974440

Afful, K. D. (1990). *The Maritime Commons : Digital Repository of the World Maritime Marine oil pollution on the coast of Ghana Dt :*

Ahmed, A., & Gasparatos, A. (2020). Multi-dimensional energy poverty patterns around industrial crop projects in Ghana: Enhancing the energy poverty alleviation potential of rural development strategies. *Energy Policy*, *137*(March 2019), 111123. https://doi.org/10.1016/j.enpol.2019.111123

Akah, I. (2015). *Africa : Diversity and Development The impact of small-scale gold mining on mining communities in Ghana Isaac Kojo Arah University of New England Ho Polytechnic*. *November 2014*, 1–18.

Akpalu, W., Dasmani, I., & Aglobitse, P. B. (2011). Demand for cooking fuels in a developing country: To what extent do taste and preferences matter? *Energy Policy*, *39*(10), 6525–6531. https://doi.org/10.1016/j.enpol.2011.07.054

Amoatey, N. K., Darmey, J., & Tabbicca, K. E. (2023). *Estimation of the Methane Generation Potential of the Tamale Landfill Site Using LandGEM **. *1*, 27–32.

Amoah, M., Deho, M., Sarfo, N., & Derkyi, A. (2022). The role of renewable energies in sustainable development of Ghana. *Scientific African*, *16*, e01199. https://doi.org/10.1016/j.sciaf.2022.e01199

Amoako-Tuffour, M. E. E. and J. (2016). A review of the trends in Ghana's power sector. *Energy, Sustainability and Society*, *2016*. https://doi.org/10.1186/1687-6180-2011-78

Annan, J., Arthur, Y., & Quanah, E. (2015). Modelling Transport Energy Demand in Ghana: The Policy Implication on Ghanaian Economy. *British Journal of Economics, Management & Trade*, *10*(1), 1–12. https://doi.org/10.9734/bjemt/2015/18378

Antwi-Agyei, P., Dougill, A. J., Agyekum, T. P., & Stringer, L. C. (2018). Alignment between nationally determined contributions and the sustainable development goals for West Africa. *Climate Policy*, *18*(10), 1296–1312. https://doi.org/10.1080/14693062.2018.1431199

Ankrah, I., & Lin, B. (2020). Renewable energy development in Ghana: Beyond potentials and commitment. *Energy*, *198*. https://doi.org/10.1016/j.energy.2020.117356

Antwi-Agyei, P., Dougill, A. J., Agyekum, T. P., & Stringer, L. C. (2018). Alignment between nationally determined contributions and the sustainable development goals for West Africa. *Climate Policy*, *18*(10), 1296–1312. https://doi.org/10.1080/14693062.2018.1431199

Apeaning, R. W. (2012). ~ *In Christ alone my hope is found ~*. *May*.

Arthur, E. (2022). Energy development: A global perspective and advances in Ghana. *AIMS Energy*, *10*(2), 306–339. https://doi.org/10.3934/energy.2022017

Arthur, J. L., & Amo-fosu, C. (2020). *Oil and gas exploitation in the Ghanaian context : The balance of benefits and challenges*. *14*(July), 177–182. https://doi.org/10.5897/AJEST2020.2856

Arthur, R., Baidoo, M. F., & Antwi, E. (2011). Biogas as a potential renewable energy source: A Ghanaian case study. *Renewable Energy*, *36*(5), 1510–1516. https://doi.org/10.1016/j.renene.2010.11.012

Ashaley, R., Namara, Horowitz, L., Nyamadi, B., & Barry, B. (2011). Land degradation in the Upper East region of Ghana, West Africa. *Center for Policy Integration and Resources Managemnt (Cpirm)*, 9. http://agriskmanagementforum.org/sites/agriskmanagementforum.org/files/Documents/IFPRI - Irrigation in Ghana.pdf

Asumadu-sarkodie, S., & Owusu, P. A. (2016). *A review of Ghana ' s solar energy potential*. *September*. https://doi.org/10.3934/energy.2016.5.675

Asumadu-Sarkodie, S., & Owusu, P. A. (2017). The relationship between carbon dioxide emissions, electricity production and consumption in Ghana. *Energy Sources, Part B: Economics, Planning and Policy*, *12*(6), 547–558. https://doi.org/10.1080/15567249.2016.1227885

Author, R., Adjei, K. A., & Dramani, J. B. (2020). *Cost-benefit Analysis of Interventions to Improve Electricity Access in Ghana Ghana Priorities*.

Awuku, S. A., Bennadji, A., Muhammad-Sukki, F., & Sellami, N. (2022a). Promoting the solar industry in ghana through effective public-private partnership (Ppp): Some lessons from South Africa and Morocco. *Energies*, *15*(1). https://doi.org/10.3390/en15010017

Awuku, S. A., Bennadji, A., Muhammad-Sukki, F., & Sellami, N. (2022b). Public-private partnership in Ghana's solar energy industry: The history, current state, challenges, prospects and theoretical perspective. *Energy Nexus*, *6*(November 2021), 100058. https://doi.org/10.1016/j.nexus.2022.100058

Ayo, D., Arthur, J. L., & Adinkrah-Appiah, K. (2021). Economic Benefits of Energy Efficiency to the Petroleum Refineries in Ghana: A Case of Tema Oil Refinery (TOR). *Open Journal of Energy Efficiency*, *10*(04), 121–135. https://doi.org/10.4236/ojee.2021.104008

Bawakyillenuo, S., Crentsil, A. O., Innocent, K., Danquah, S., & Boakye-, E. B. (2021). The landscape of energy for cooking in Ghana : A review. *Modern Energy Cooking Services*, *June*, 1–56.

Berkouwer, S. B., Biscaye, P. E., Puller, S., & Wolfram, C. D. (2022). Disbursing emergency relief through utilities: Evidence from Ghana. *Journal of Development Economics*, *156*(January), 102826. https://doi.org/10.1016/j.jdeveco.2022.102826

Bessah, E., Raji, A. O., Taiwo, O. J., Agodzo, S. K., Ololade, O. O., Strapasson, A., & Donkor, E. (2021). Assessment of surface waters and pollution impacts in Southern Ghana. *Hydrology Research*, *52*(6), 1423–1435. https://doi.org/10.2166/NH.2021.051

Boamah, F., & Rothfuß, E. (2018). From technical innovations towards social practices and socio-technical transition? Re-thinking the transition to decentralised solar PV electrification in Africa. *Energy Research and Social Science*, *42*(March), 1–10. https://doi.org/10.1016/j.erss.2018.02.019

Brew-hammond, A., & Essandoh, E. O. (2013). *RELATIONSHIPS BETWEEN ENERGY USE AND INCOME LEVELS , FOR HOUSEHOLDS IN GHANA*. *9*(16), 233–245.

Bukari, C., Broermann, S., & Okai, D. (2021). Energy poverty and health expenditure: Evidence from Ghana. *Energy Economics*, *103*(September), 105565. https://doi.org/10.1016/j.eneco.2021.105565

Bukari, D., Tuokuu, F. X. D., Suleman, S., Ackah, I., & Apenu, G. (2021). Ghana's energy access journey so far: a review of key strategies. *International Journal of Energy Sector Management*, *15*(1), 139–156. https://doi.org/10.1108/IJESM-02-2020-0008

CEIC, Census and Economic Information Center. "Ghana Petroleum Production". 26 August 2022. https://www.ceicdata.com/en/ghana/petroleum-production

Che, X., Zhu, B., & Wang, P. (2021). Assessing global energy poverty: An integrated approach. *Energy Policy*, *149*(June 2020), 112099. https://doi.org/10.1016/j.enpol.2020.112099

CL, Conventus Law. "Ghana- Public Procurement".

CXA, CX Associates. " The Transportation Energy Efficiency of Buildings". 27 May 2023. https://buildingenergy.cx-associates.com/2012/08/the-transportation-energy-efficiency-of-buildings/

Diawuo, F. A., Pina, A., Baptista, P. C., & Silva, C. A. (2018). Energy efficiency deployment: A pathway to sustainable electrification in Ghana. *Journal of Cleaner Production*, *186*, 544–557. https://doi.org/10.1016/j.jclepro.2018.03.088

Dickinson, K. L., Kanyomse, E., Piedrahita, R., Coffey, E., Rivera, I. J., Adoctor, J., Alirigia, R., Muvandimwe, D., Dove, M., Dukic, V., Hayden, M. H., Diaz-Sanchez, D., Abisiba, A. V., Anaseba, D., Hagar, Y., Masson, N., Monaghan, A., Titiati, A., Steinhoff, D. F., … Wiedinmyer, C. (2015). Research on Emissions, Air quality, Climate, and Cooking Technologies in Northern Ghana (REACCTING): Study rationale and protocol. *BMC Public Health*, *15*(1). https://doi.org/10.1186/s12889-015-1414-1

Duku, M. H., Gu, S., & Hagan, E. Ben. (2011). A comprehensive review of biomass resources and biofuels potential in Ghana. *Renewable and Sustainable Energy Reviews*, *15*(1), 404–415. https://doi.org/10.1016/j.rser.2010.09.033

ECG, Energy Commission of Ghana. “Energy Sector Recovery Programme (ESRP)”. http://energycom.gov.gh/public-notices/112-energy-sector-recovery-programme-esrp

ECG, Energy Commission of Ghana. “Energy Statistics” 25, April, 2023. https://energycom.gov.gh/planning/energy-statistics

ED, EnerData. “Ghana Energy Information” 26 May 2023. https://www.enerdata.net/estore/energy-market/ghana/

EEI, Energy Efficiency Intelligence. “Industrial Energy Efficiency Market Assessment in Ghana”. https://www.globalefficiencyintel.com/industrial-energy-efficiency-in-ghana-1

EG, Energy.Gov. “Energy Efficiency”. 27 May, 2023. https://www.energy.gov/eere/energy-efficiency

EIA, Energy Information Administration. “International Data” 25, April, 2023. https://www.eia.gov/international/data/world

Statista, Statista.com. “Energy sector in Ghana - statistics & facts” 25, April, 2023. https://www.statista.com/topics/10426/energy-sector-in-ghana/

EJN, Earth Journalism Network. “Ghana is determined to reduce emission in the transport sector” 28 May 2023. https://earthjournalism.net/stories/ghana-is-determined-to-reduce-emission-in-the-transport-sector

Eni, F., & Mattei, E. (2017). *Access to Energy and Economic Development in Ghana*. *December*.

Emmanuel, A. Y., Jerry, C. S., & Dzigbodi, D. A. (2018). Review of environmental and health impacts of mining in Ghana. *Journal of Health and Pollution*, *8*(17), 43–52. https://doi.org/10.5696/2156-9614-8.17.43

Energy Commission-Ghana. (2020). National Energy Statistics 2000 - 2019. In *www.energycom.gov.gh* (Vol. 27, Issue 9). https://doi.org/10.1088/0031-9112/27/9/008

Energy Commission-Ghana. (2021). *2021 ENERGY OUTLOOK FOR GHANA, Demand and Supply Outlook* (Issue April).

Energy Commission. (2020). *Evaluation of Energy Efficiency Policy Measures for Cooling Appliances in Ghana*. 1–29. www.energycom.gov.gh

Energy Commission of Ghana. (2020). *Energy Commission, Ghana 2020 Energy (Supply and Demand) Outlook for Ghana*. *2020*(April), 1–27. http://www.energycom.gov.gh/files/Energy Commission - 2016Energy Outlook for Ghana_final.pdf

Energy Sustainability and Society. "A review of the trends in Ghana's power sector" 26 May, 2023. https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-016-0075-y

Environment, M. of. (1999). *ENVIRONMENTAL ASSESSMENT REGULATIONS 1999 1 . Undertaking requiring registration and issue of environmental permit 2 . Existing undertakings 3 . Environmental impact assessment 4 . Application for environmental permit 5 . Initial assessment by screening o*.

EP,Energypedia."Ghana's Energy Situation". 25 August 2022. https://energypedia.info/wiki/Ghana_Energy_Situation *Evidence-from-Ghana-Oil-discovey*. (n.d.).

ESIA, ESI Africa. "Electricity Company of Ghana: Power purchase agreement on hold pending a legal battle". 07 November, 2022. https://www.esi-africa.com/top-stories/electricity-company-of-ghana-power-purchase-agreement-on-hold-pending-a-legal-battle/ https://conventuslaw.com/report/ghana-public-procurement-a-cq-legal-feature-in-the/

FAO, Food and Agriculture Organization of the United Nations. "Ghana- Energy Commission Act (Act 541). https://www.fao.org/faolex/results/details/en/c/LEX-FAOC093004/

Fiagbe, Y. A. K. (2017). Need For Coastal Water Management Tool For Oil Spill Simulation In Ghana. *International Journal of Scientific & Technology Research*, *06*(09), 270–274.

Gauri Singh, S. A. N. and M. Y. S. (2015). *GHANA RENEWABLES READINESS ASSESSMENT*.

GBN, Ghana Business News. "Ghana updates coastal area environmental sensitive atlas" 2023 https://www.ghanabusinessnews.com/2023/02/23/ghana-updates-coastal-area-environmental-sensitive-atlas/

GD, Global Data. "Ghana Renewable Energy Policy Handbook, 2022 Update". https://www.globaldata.com/store/report/ghana-renewable-energy-government-regulation-policy-analysis/#:~:text=National%20Energy%20Policy,-The%20National%20Energy&text=The%20policy%20emphasizes%20renewable%20

energy,efficient%20and%20sustainable%20energy%20generation

Ghana, P. of. (n.d.). *Renewable_Energy_Act_2011_Act_832.Pdf.Pdf*.

Ghana Renewable Energy Master Plan. (2019).

Ghana, P. of. (2020). *(act 1045)*. *2020*(Act 1045).

GODI, Ghana Open Data Initiative. "Export of Petroleum Products (Kilotonnes). 26 August 2022. https://data.gov.gh/dataset/import-petroleum-products-kilotonnes

GODI, Ghana Open Data Initiative. "Import of Petroleum Products (Kilotonnes). 26 August 2022. https://data.gov.gh/dataset/import-petroleum-products-kilotonnes

GSS. (2019). Ghana Living Standards Survey round 7 (GLSS7), Main Report. *Ghana Statistical Service*, 1–343. https://statsghana.gov.gh/gsspublications.php?category=MTAwMjg3Mzk3NC4zMDc=/webstats/1opr93rn57

GSS, Ghana Statistical Service. "Population of Regions and Districts Report" 07 May, 2023. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203E_Economic%20Activity.pdf

Gyamfi, S., Modjinou, M., & Djordjevic, S. (2015). Improving electricity supply security in Ghana - The potential of renewable energy. *Renewable and Sustainable Energy Reviews*, *43*, 1035–1045. https://doi.org/10.1016/j.rser.2014.11.102

Halkos, G. E., & Aslanidis, P. C. (2023). *Achieving Sustainable Development*.

Herman, R. J., Vollebergh, H. R. J., & Brink, C. (2020). *What Can We Learn from EU ETS ? What Can We Learn from EU ETS ?*

Honorati and de Silva. (2016). *Expanding Job Opportunities in Ghana*.

Hymer, S. H. (1970). *Economic History Association Economic Forms in Pre-Colonial Ghana Author (s): Stephen H . Hymer Source : The Journal of Economic History , Vol . 30 , No . 1 , The Tasks of Economic History Published by : Cambridge University Press on behalf of the Econo*. *30*(1), 33–50.

IEA, International Energy Agency. "Energy Efficiency 2020-Buildings". 27 May, 2023. https://www.iea.org/reports/energy-efficiency-2020/buildings

IEA, International Energy Agency. "Where to start: Energy efficiency potential in buildings". 27 May 2023. https://iea.blob.core.windows.net/assets/imports/events/610/Buildings.2_Energy_efficiency_potential.pdf

IEA, International Energy Agency. "National Renewable Energy Action Plan (NREAP) through 2020". https://www.iea.org/policies/5673-national-renewable-energy-action-plan-nreap-through-2020.

IHA, International Hydropower Association. "Volta River Authority". 12 June, 2023. https://www.hydropower.org/our-members/volta-river-authority

IISD, International Institute for Sustainable Development. "World Summit on Sustainable Development" 24, April 2023. https://enb.iisd.org/negotiations/world-summit-sustainable-development-2002-wssd

International Energy Agency (IEA), I. (2007). Energy Indicators for Sustainable Development : Guidelines and. *Special Report*, 7–140. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1222_web.pdf

IO, IntechOpen. "The Impact of Energy Efficiency Programmes in Ghana" 26, May 2023. https://cdn.intechopen.com/pdfs/79827.pdf

Irena. (2015). *GHANA RENEWABLES READINESS ASSESSMENT*.

ISAZADE, S., & ALTAN, M. (2023). A Review of Literature on Measuring Energy Poverty. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi*, *24*(2), 336–361. https://doi.org/10.17494/ogusbd.1241989

ITOPF, International Tankers Owners Pollution Federation Limited "Ghana Spill Notification Points"https://www.itopf.org/knowledge-resources/countries-territories-regions/ghana/

ITA, International Trade Administration. "Ghana- Country Commercial Guide". 07, November 2022.https://www.trade.gov/country-commercial-guides/ghana-energy-and-renewables

Kalitsi, E. A. K. (2003). *PROBLEMS AND PROSPECTS FOR HYDROPOWER DEVELOPMENT Prepared by The Workshop for African Energy Experts on Operationalizing the NGPAD Energy Initiative Problems and Prospects for Hydropower Development in Africa*. *June*.

Kanyoke, E. L. (2004). *Rising Transport Pollution in The Accra – Tema Metropolitan Area ,*.

Kemausuor, F., Yaw, G., Brew-hammond, A., & Duker, A. (2011). A review of trends , policies and plans for increasing energy access in Ghana. *Renewable and Sustainable Energy Reviews*, *15*(9), 5143–5154. https://doi.org/10.1016/j.rser.2011.07.041

Knoema, Knoema.com "Ghana - Total primary energy consumption" 25, April, 2023. https://knoema.com/atlas/Ghana/Primary-energy-consumption

Kipkoech, R., Takase, M., Kofi, E., & Afrifa, A. (2022). *Renewable Energies in Ghana in Relation to Market Condition , the Environment , and Food Security*. *2022*.

Kolbasov, O. S. (1992). UN Conference on Environment and Development. *Izvestiya - Akademiya Nauk, Seriya Geograficheskaya*, *6*(June), 47–54. https://doi.org/10.4135/9781412971867.n128

Koomson, I., & Danquah, M. (2021a). Financial inclusion and energy poverty : Empirical evidence from Ghana. *Energy Economics, 94,* 105085. https://doi.org/10.1016/j.eneco.2020.105085

Koomson, I., & Danquah, M. (2021b). Financial inclusion and energy poverty: Empirical evidence from Ghana. *Energy Economics*, *94*, 105085. https://doi.org/10.1016/j.eneco.2020.105085

Kuamoah, C. (2020a). *Renewable Energy Deployment in Ghana : The Hype , Hope and Reality*. https://doi.org/10.1177/0975087819898581

Kuamoah, C. (2020b). Renewable Energy Deployment in Ghana: The Hype, Hope and Reality. *Insight on Africa*, *12*(1), 45–64. https://doi.org/10.1177/0975087819898581

Kumi, E. N. (2017). *The Electricity Situation in Ghana: Challenges and Opportunities*. www.cgdev.orgwww.cgdev.org

Kwakwa, P. A. (2020). What determines renewable energy consumption? Startling evidence from Ghana. *International Journal of Energy Sector Management*, *15*(1), 101–118. https://doi.org/10.1108/IJESM-12-2019-0019

Kwakwa, P. A., Aboagye, S., & Adjei Kwakwa, P. (2014). *Environmental degradation effect of agricultural and industrial growth in Ghana Environmental Sustainability View project EnvironmEntal DEgraDation EffEct of agricultural anD inDustrial growth in ghana*. *2009*, 2011. http://www.publishingindia.com

Lin, B., & Agyeman, S. D. (2019). Assessing Ghana's carbon dioxide emissions through energy consumption structure towards a sustainable development path. *Journal of Cleaner Production*, *238*, 117941. https://doi.org/10.1016/j.jclepro.2019.117941

Lin, B., & Okyere, M. A. (2020). *Multidimensional Energy Poverty and Mental Health : Micro-Level Evidence from Ghana*.

Mahama, M., Derkyi, N. S. A., & Nwabue, C. M. (2020). Challenges of renewable energy development and deployment in Ghana: perspectives from developers. *GeoJournal*. https://doi.org/10.1007/s10708-019-10132-z

Maccarthy, D. S., Zougmoré, R. B., Akponikpè, P. B. I., Koomson, E., Savadogo, P., & Adiku, S. G. K. (2018). Assessment of Greenhouse Gas Emissions from Different Land-Use Systems: A Case Study of CO2 in the Southern Zone of Ghana. *Applied and Environmental Soil Science, 2018*. https://doi.org/10.1155/2018/1057242

Mawusi, S. K., Shrestha, P., Xue, C., & Liu, G. (2023). Heliyon Review article A comprehensive review of the production , adoption and sustained use of biomass pellets in Ghana. *Heliyon*, *9*(6), e16416. https://doi.org/10.1016/j.heliyon.2023.e16416

Mensah, K., Boahen, S., & Amoabeng, K. O. (2017). Renewable Energy Situation in Ghana:Review and Recommendations for Ghana's Energy Crisis. *Proceedings of the 1st GHASKA Innovation Conference*, *May 2017*, 1–7.

MG, Modern Ghana. "Ghana Now Has 16 Regions" 07 May, 2023. https://www.modernghana.com/news/916140/ghana-now-has-16-regions.html

Miescher, S. F. (2021). Ghana's akosombo dam, volta lake fisheries & climate change. *Daedalus*, *150*(4), 124–142. https://doi.org/10.1162/DAED_a_01876

Minerals Commission of Ghana. (2006). *Minerals and Mining Act , 2006*. *March*, 1–59. http://www.sdsg.org/wp-content/uploads/2011/06/Ghana-Minerals-Act-2006.pdf

Ministry of Power. (2015). National Energy Efficiency Action Plan (NEEAP) Ghana Period [2015-2020]. *Sustainable Energy for All*, 1–37.

Ministry of Energy, G. (2019). *Ghana Renewable Energy Master Plan*.

Ministry of Environment, Science, T. and I. (2021). *New Climate Institute*. *August*.

MOFEP, G. (2011). *Ppp_Policy.Pdf*.

Moudene, K., El-oud, R., Ejbari, R., & Amedjar, A. (2023). *Renewable Energy and Economic Growth in*. 401–413. https://doi.org/10.4236/jhrss.2023.112023

MPRA, Munich Personal RePEc Archives. "What Factors Drive Energy Consumption in Ghana?" 26, May 2023. https://mpra.ub.uni-muenchen.de/66095/1/MPRA_paper_66095.pdf

Muhammad-Sukki, Sellami, A., & Nazmi, F. (2022). *Promoting the Solar Industry in Ghana through Effective*. *15*(17), 1–14.

National Energy Policy. (2010).

Nationally, U., Contribution, D., & Agreement, P. (2021). *Ghana Updated Nationally Determined Contribution under the*. *September*.

Nations, U., Convention, F., & Change, C. (2015). *Ghana ' s First Biennial Update Report Ghana ' s First Biennial Update Report*.

Nyasapoh, M. A., Elorm, M. D., & Derkyi, N. S. A. (2022). The role of renewable energies in sustainable development of Ghana. *Scientific African*, *16*, e01199. https://doi.org/10.1016/j.sciaf.2022.e01199

Okpanachi, E., Ambe-uva, T., & Fassih, A. (2022). Energy regime reconfiguration and just transitions in the Global South : Lessons for West Africa from Morocco ' s comparative experience. *Futures, 139*(August 2021), 102934. https://doi.org/10.1016/j.futures.2022.102934

Obeng-Darko, N. A. (2018). Policy Trends on Renewable Energy for Decentralised Electrification as a Catalyst for Achieving Goal Seven of the Sustainable Development Goals in sub-Saharan Africa. The Case of Ghana. *Renewable Energy Law & Policy Review*, *8*(4), 12–24. https://search.ebscohost.com/login.aspx?direct=true&db=lgs&AN=130903304&lang=pt-br&site=ehost-live

Oyewo, A. S., Sterl, S., Khalili, S., & Breyer, C. (2023). Review Highly renewable energy systems in Africa : Rationale , research , and recommendations. *Joule, 7*(7), 1437–1470. https://doi.org/10.1016/j.joule.2023.06.004

Office of Planning Commision. (1964). *Seven Year Development plan 1963/64 to 1969/70*. 303. https://www.mendeley.com/viewer/?fileId=1616ab59-65c1-2565-16ba-a943d71c7d8a&documentId=56998e6d-aa4c-3b5b-830e-c7e93716c249

Ofori, C. G., Aboagye, A. Q. Q., & Afful-dadzie, A. (2022). A real options approach to assessing the cost savings potential of renewable energy adoption among SMEs in Ghana A real options approach to assessing the cost savings potential of. *Climate Policy*, *22*(7), 851–864. https://doi.org/10.1080/14693062.2022.2095332

Opoku, E. K., Adjei, K. A., Gyamfi, C., Vuu, C., Appiah-Adjei, E. K., Odai, S. N., & Siabi, E. K. (2022). Quantifying and analysing water trade-offs in the water-energy-food nexus: The case of Ghana. *Water-Energy Nexus*, *5*(2022), 8–20. https://doi.org/10.1016/j.wen.2022.06.001

OWID, Our World in Data. "CO2 Emissions" 15 July 2022. https://ourworldindata.org/co2-emissions

OWID, Our World in Data. "What share of people have access to electricity?" 3 November 2022. https://ourworldindata.org/energy-access

Paudel, D., Jeuland, M., & Lohani, S. P. (2021). Cooking-energy transition in Nepal: Trend review. *Clean Energy, 5*(1), 1–9. https://doi.org/10.1093/ce/zkaa022

Pelicaric, D., Petanjek, B. B., & Jurisic, M. K. (2008). Ghana National Climate Change Policy Ministry. *Atemwegs- Und Lungenkrankheiten, 34*(7), 261–265.

Pelizan, L. (2019a). *Solar Home Solutions Using a Pay-As-You-Go Model in Ghana : Exploring the Opportunity*. *December*, 1–13.

Pelizan, L. (2019b). *The Cooking Fuel Sector in Ghana*. *December*.

Pennise, D., Brant, S., Agbeve, S. M., Quaye, W., Mengesha, F., Tadele, W., & Wofchuck, T. (2009). Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia. *Energy for Sustainable Development*, *13*(2), 71–76. https://doi.org/10.1016/j.esd.2009.04.003

Sackey, D. M., Asiedu, R. O., & Jehuri, A. B. (2020). *Analysis of latent impeding factors to solar photovoltaic investments in Ghana*. *14*(4), 669–682. https://doi.org/10.1108/IJESM-08-2019-0005

Saisirirat, P., Rushman, J. F., Silva, K., & Chollacoop, N. (2022). Contribution of Road Transport to the Attainment of Ghana's Nationally Determined Contribution (NDC) through Biofuel Integration. *Energies*, *15*(3). https://doi.org/10.3390/en15030880

Sakah, M., de la Rue du Can, S., Diawuo, F. A., Sedzro, M. D., & Kuhn, C. (2019). A study of appliance ownership and electricity consumption determinants in urban Ghanaian households. *Sustainable Cities and Society*, *44*(October 2018), 559–581. https://doi.org/10.1016/j.scs.2018.10.019

Sakah, M., Diawuo, F. A., Katzenbach, R., & Gyamfi, S. (2017). Towards a sustainable electrification in Ghana: A review of renewable energy deployment policies. In *Renewable and Sustainable Energy Reviews* (Vol. 79, pp. 544–557). Elsevier Ltd. https://doi.org/10.1016/j.rser.2017.05.090

SEforAll, Sustainable Energy for All. "Country work – Ghana". 28 May 2023. https://www.seforall.org/impact-areas/country-engagement/country-work-ghana

SEforAll, Sustainable Energy for All. "Ghana Leads on Sustainable Energy for All". 23 August 2022. https://www.seforall.org/news/ghana-leads-on-sustainable-energy-for-all.

Senanu, A., Kukah, K., & Edwards, D. J. (2022). *Reasons for entering into Ghanaian public-private partnership (PPP) power projects*. https://doi.org/10.1108/JEDT-11-2021-0631

Serwaa, G., Kemausuor, F., & Brew-hammond, A. (2015). *Energy access indicators and trends in Ghana*. *30*(2014), 317–323. https://doi.org/10.1016/j.rser.2013.10.032

Siksnelyte-Butkiene, I., Streimikiene, D., Lekavicius, V., & Balezentis, T. (2021). Energy poverty indicators: A systematic literature review and comprehensive analysis of integrity. *Sustainable Cities and Society*, *67*(September 2020), 102756. https://doi.org/10.1016/j.scs.2021.102756

SREP Sub-Committee. (2015). *Lan for*.

STATISTA. “Energy sector in Ghana - statistics & facts”. 29 May, 2023. https://www.perplexity.ai/search/e5c03083-6bf0-4894-9cff-325ba7fd3faa?s=u

STATISTA, Statista. “Share of electricity consumption in Ghana as of 2020, by sector” 26 May 2023. https://www.statista.com/statistics/1298435/share-of-electricity-consumption-in-ghana-by-sector/

SS, Sustainable Square. “Has the Republic of Ghana Achieved its Renewable Energy Target for Electricity in 2020”? 23 August 2022. https://sustainablesquare.com/have-the-republic-of-ghana-achieved-its-renewable-energy-target-for-electricity-in-2020/

Takase, M., Aboah, M., & Kipkoech, R. (2022). A review on renewable energy potentials and energy usage statistics in Ghana. *Fuel Communications*, *11*(March), 100065. https://doi.org/10.1016/j.jfueco.2022.100065

Tietenberg, T., & States, U. (n.d.). *Carbon Pricing: Lessons Derived from Experience**. 151–180.

Trimble, C., Kojima, M., Perez Arroyo, I., & Mohammadzadeh, F. (2016). Financial Viability of Electricity Sectors in Sub-Saharan Africa: Quasi-Fiscal Deficits and Hidden Costs. *Financial Viability of Electricity Sectors in Sub-Saharan Africa: Quasi-Fiscal Deficits and Hidden Costs*, *August*. https://doi.org/10.1596/1813-9450-7788

TWB, The World Bank, “Ghana Begins Receiving Payments for Reducing Carbon Emissions in Forest Landscapes” 2023. https://www.worldbank.org/en/news/press-release/2023/01/24/ghana-begins-receiving-payments-for-reducing-carbon-emissions-in-forest-landscapes

TWB, The World Bank. “Ghana Can Turn Climate Challenges into Opportunities for Resilient and Sustainable Growth, says new World Bank Group Report” 2022. https://www.worldbank.org/en/news/press-release/2022/11/01/ghana-can-turn-climate-challenges-into-opportunities-for-resilient-and-sustainable-growth-says-new-world-bank-group-report

TWB, The World Bank, “Ghana Signs Landmark Deal with World Bank to Cut Carbon Emissions and Reduce Deforestation” 2019. https://www.worldbank.org/en/news/press-release/2019/07/09/ghana-signs-landmark-deal-with-world-bank-to-cut-carbon-emissions-and-reduce-deforestation

TWB, the World Bank. “Population Density Data” 15, March, 2023. https://data.worldbank.org/

Twerefou, D. K., & Abeney, J. O. (2020). Efficiency of household electricity consumption in Ghana. *Energy Policy, 144*(April), 111661. https://doi.org/10.1016/j.enpol.2020.111661

UN, United Nations. "Sustainable Development Goals" 21, November 2022. https://www.un.org/sustainabledevelopment/

UNECFA, United Nations Economic Commission for Africa. "Regulatory Review of the Electricity Market in Ghana". https://repository.uneca.org/bitstream/handle/10855/46743/b11999111.pdf?sequence=3&isAllowed=y

UNEP, United Nations Environmental Programme "Energy SMEs in sub-Saharan Africa: Outcomes, barriers and prospects in Ghana, Senegal, Tanzania and Zambia". 15, June 2023.

UNEP, United Nations Energy Programme. "Energy Profile: Ghana" 25, April, 2023. https://www.unep.org/resources/report/energy-profile-ghana

https://unepccc.org/publications/energy-smes-in-sub-saharan-africa-outcomes-barriers-and-prospects-in-ghana-senegal-tanzania-and-zambia/

Vassiliades, C., Diemuodeke, O. E., Yiadom, E. B., Prasad, R. D., & Dbouk, W. (2022). *Policy Pathways for Mapping Clean Energy Access for Cooking in the Global South — A Case for Rural Communities*.

Vera, I., Langlois, L., & Rogner, H. (2001). Indicators for Sustainable Energy Development. *Indicators for Sustainable Energy Development, Presented at the Ninth Session of the Commission on Sustainable Development, 16-27 April 2001*, 5–16.

WB, World Bank. "World Bank National Accounts Data (GDP, Ghana)" 07 May, 2023 https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=GH

WBG, World Bank Group. "Making Power Affordable for Africa and Viable for Its Utilities".07November,2022. https://openknowledge.worldbank.org/bitstream/handle/10986/25091/108555.pdf

WD, World Data. "Energy consumption in Ghana". 29 May 2023. https://www.worlddata.info/africa/ghana/energy-consumption.php

Wesseh, P. K., & Lin, B. (2018). Energy consumption, fuel substitution, technical change, and economic growth: Implications for CO2 mitigation in Egypt. *Energy Policy, 117*(March), 340–347. https://doi.org/10.1016/j.enpol.2018.03.022

WPR, World Population Review. "population of Cities in Ghana 2023" 07 May, 2023 https://worldpopulationreview.com/countries/cities/ghana

WT, Water Technology. "Bui Dam Hydroelectricity Project, Ghana." 07 November 2022. https://www.water-technology.net/projects/bui-dam-hydro-power-ghana/

XN, XihuaNet. "Ghanaian innovator develops affordable houses from recycled plastic waste". 28 May 2023. https://www.xinhuanet.com/english/2021-06/09/c_139998728.htm

Yiran, G. A. B., Ablo, A. D., & Asem, F. E. (2020). Urbanisation and domestic energy trends: Analysis of household energy consumption patterns in relation to land-use change in peri-urban Accra, Ghana. *Land Use Policy*, *99*(November 2019), 105047. https://doi.org/10.1016/j.landusepol.2020.105047