CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical Agrisciences

What factors influence the adoption of biogas technology as a renewable energy source in Ghana?

MASTER'S THESIS

Prague 2024

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Declaration

I hereby declare that I have done this thesis entitled **What factors influence the adoption of biogas technology as a renewable energy source in Ghana?** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, April, 2024

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Thaddeus Tawiah Bilson

Acknowledgements

I am thank God for the grace and blessings during my two-year master's program. I am also grateful to my family for their strong support during my studies and also my colleagues for their solidarity throughout this journey.

I thank the Biogas Research Team, led by my supervisor, doc. Ing. Hynek Roubík, Ph.D., for their support and guidance in writing my thesis.

Finally, I am grateful to the Czech University of Life Sciences, particularly the Faculty of Tropical Agrisciences (FTZ), for offering an excellent teaching and learning environment. It has been an awesome journey.

Thank you.

Abstract

Energy is regarded as the most important aspect of socioeconomic development and has a direct impact on the overall progress of a nation. The bulk of energy supply in Ghana is met from wood fuels, that is, firewood and charcoal. Wood fuels account for approximately 71.1% of the total primary energy supply and approximately 60% of the final energy demand. Wood fuel contributes immensely to the primary energy supply to the country, with crude oil and hydropower making up the rest. Interest in biogas technology in Ghana began in the late 1960s, but it was not the mid-1980s that biogas technology received the needed attention from the government. The purpose of this study was to determine the factors influencing the adoption of biogas as a renewable energy source in the Central Region of Ghana. The study adopted the mixed method. Both descriptive and analytical methods were used in the study. Using questionnaires and an interview guide, field data was collected from hundred (100) individuals and two (2) senior officers from each of these 5 institutions (energy and environmental sector) in the Central Region of Ghana. The data from the respondents were analysed using the logit regression model. The Statistical Package for Social Science (SPSS), content analysis, and thematic narratives were used to analyse the data. The study found out that several factors influence people to use biogas. These include: cost of biogas, environment friendly nature, recommendations from people etc. It was also found out that Ghana produces 10.29 % renewable energy while it consumes 8.79% megawatts annually. A myriad of factors influence the adoption of biogas technology in Ghana. The study highlights the affordability and environmental benefits of biogas, emphasizing the importance of public education and international cooperation for renewable energy adoption. It suggests that the United Nations and African Union collaborate to promote renewable energy as a global public good, advocating for reduced barriers to knowledge sharing and technology transfer to ensure accessibility for all.

Key words: Renewable energy, organic waste, anaerobic, environment, wood fuel.

Table of contents

List of tables and Figures

List of the abbreviations

ABBD -Baffled Bio-Digester

BCEL -Beta Civil Engineering Limited

BEL -Biogas Engineering Ltd

BTAL -Biogas Technology Africa Limited

CFMP-Community Forest Management Project

CNG-Compressed Natural Gas

CSIR- Council for Scientific and Industrial Research

EC- Energy Commission

EPA-Environmental Protection Agency

FAO-Food and Agricultural Organization

FDBD- fixed dome biodigester

FITs-Feed-in Tariffs

FSD-Forestry Services Division

GCRF-EPSRC- Global Challenge Research Fund

GIZ- Deutsche Gesellschaft für Internationale Zusammenarbeit

GRIDCo- Ghana Grid Company Limited

GTZ-German Agency for Technical Assistance

GWP -Global Warming Potential

IAP- indoor air pollution

IBD- integrated Bio-digester

IIR -Institute of Industrial Research

IPPs-Independent Power Producers

KNUST-Kwame Nkrumah University of Science and Technology

LNG- Liquefied Natural Gas

NGO’s- Non governmental agencies

NREG -Natural Resources and Environmental Governance

PABBD -Portable Baffled Bio-Digester

PURC-Public Utilities Regulatory Commission

RET- Renewable Energy Technology

CHAPTER ONE

1.0 Introduction

This chapter covers the background of the study, a statement of the research problem, objectives, and questions. It also looks at the justification of the study, its limitations, and its scope of the study.

1.1 Overview of the study

Biogas technology since its introduction in 1850 has efficiently impacted the global economy (Ahiataku-Togobo 2019). The need to reduce waste, secure other sources of renewable energy, and avoid rapid depletion of the ozone layer hinted at the introduction of biogas technology.

The digestion of energy crops through anaerobic digestion residues, and waste is increasing the reduction of greenhouse gas emissions and also facilitating the sustainable development of the energy supply (Weiland 2009). Biogas production provides a versatile carrier of renewable energy. For example, methane can be used to replace fossil fuels in both heat and power generation and as a vehicle fuel (Xinshan et al. 2005). For biogas production, various types are applied that can be classified into wet and dry fermentation systems. The most commonly applied are wet digester systems that use vertical stirred tank digester with different types of stirrers depending on the origin of the feedstock. Biogas is mainly utilized in engine-based combined heat and power plants, whereas micro gas turbines and fuel cells are expensive alternatives that need further development work to reduce the costs and increase their reliability. The upgrading and utilization of gas as renewable vehicle fuel or injection into the natural gas grid are of increasing interest because the gas can be used more efficiently. The digestate from anaerobic fermentation is a valuable fertilizer due to the increased availability of nitrogen and the better short-term fertilization effect. (Glowacka et al. 2020).

Global energy demand is growing, and about 88% of this demand is met by fossil fuels. There has been an increase in greenhouse gas emissions over the past decade.

To minimize global warming and its related issues, greenhouse emissions must be reduced. However, the introduction of biogas technology has reduced these emissions by a significant amount. Many countries have adopted the use of this technology to supplement their energy crisis. Ghana has so far also adopted this technology, but it is not widely known (Grim & Johansson 2012).

The bulk of the energy supply in Ghana is met from wood fuels, that is, firewood and charcoal. Wood fuels account for approximately 71.1% of the total primary energy supply and approximately 60% of the final energy demand. About 72% of the nation's primary energy source in 2008 came from wood fuel; the remaining 28% came from hydropower and crude oil. Interest in biogas technology in Ghana began in the late 1960s, but it was not until mid-1980 that biogas technology received the needed attention from the government. The government’s intervention in dissemination programs before the mid-1980s focused on providing energy for domestic cooking. The rapid depletion of the base of fuel resources coupled with the projected increase in the demand for wood fuels in the future, with its attendant social and environmental effects, brought into sharp focus the need for alternative sources of cooking fuel to be developed and exploited. Subsequently, biogas technology was selected as one such option to reduce the incidence of deforestation. (Arthur, Richard & Baidoo, Martina & Antwi, Edward 2011)

1.2 Statement of the problem

The research and development of biogas in Ghana dates back to the late 1960s (Agyekum 2020). The total number of biogas plants in Ghana is unknown, but according to estimates, more than 200 biogas plants have been constructed. The actual number of plants could be higher due to unknown projects started by individuals and small companies (Bensah et al. 2010).

The objective has mainly been to provide energy for cooking and electricity generation. The treatment of organic matter to address sanitation issues and the use of digested slurry for agriculture have not been the main driving factor for investment, as many of the biodigester plants have failed to function shortly after being installed.

The use of bio-digester plants is also not commonplace in Ghana. Few institutions and individuals have adopted this technology and are mainly concentrated in urban areas. In 1997, the Energy Commission (EC) was founded, among other functions, to develop, regulate, and manage renewable energy resources in Ghana. In 2006, the EC developed the Strategic National Energy Plant (SNEP) a policy document that defined the role of various energy sources, setting targets for each within twenty years. From SNEP, biomass-based energy, in addition to its direct use as wood fuel (firewood and charcoal), has been exploited to a very limited extent in Ghana. Wood fuel represents the traditional energy source in Ghana and represents 60% of the total energy used. (Cudjoe Bensah & Brew-Hammond 2010).

However, since 1990, there has been a rise in the use of biogas technology. Government institutions have begun to install this technology in schools and communities. Individuals and educational institutions have also adopted this technology to supplement their energy consumption. This study sought to review the factors that have influenced the adoption of biogas technology as a renewable energy source by both institutions and individuals in Ghana.

1.3 Research questions

The study sought to answer the following research questions:

1. What is the general importance of biogas technology as a renewable energy source in Ghana?
2. What is the capacity of Ghana in the production and consumption of renewable energy ?
3. What are the factors that influence the adoption of biogas technology as a renewable energy source in Ghana?
4. What are the limitations of investments in renewable energy generation in Ghana?

1.4 Objectives of the study

The study sought to achieve the following objectives:

1. Access the general importance of biogas technology as a renewable energy source in Ghana.
2. Determine the capacity of Ghana in the production and consumption of renewable energy
3. Analyse the factors for the adoption of biogas technology as a renewable energy source in Ghana.
4. Examine the limitations of investments in renewable energy generation in Ghana.

1.5 Significance of the study

The study would be significant in several dimensions: Among them are the following:

The study would assist stakeholders such as rural communities, NGOs, investors, Government, Local renewable energy vendors and among others by boosting investor confidence in the renewable energy sector.

The findings of the study could guide the decision making especially by the government and organisations involved in promotion of biogas technology and other related renewable energy technologies in Ghana.

Furthermore, the study would improve the academic experience of the researcher and further contribute to knowledge in the area of renewable energy in Ghana.

Finally, the findings of this study would also pave the way for other interested energy researchers to replicate the problems on the ground in other regions of Ghana.

1.6 Scope of the study

This research was conducted in the Central Region of Ghana and it focused on the factors that influence the adoption of biogas as a renewable source of energy in Ghana. The study also examined Ghana's capacity to produce and consume renewable energy and the limitations of investments in renewable energy generation in Ghana. It was limited to 100 individuals and two individuals each from 5 organisations in the Central Region,Ghana.

CHAPTER TWO
LITERATURE REVIEW

In this chapter, we examine the literature that has already been written on biogas technology as a renewable energy source. It is divided into a number of sections, including those on the definition of fundamental concepts, biogas in Ghana, biogas production, anaerobic digestion, the construction of biogas plants in Ghana, the advantages and disadvantages of biogas technology in Ghana, the impact of biogas technology in Ghana, renewable energy in Ghana, and the use of biogas as a renewable energy resource in Ghana, as well as the theoretical framework.

Sub Chapter One
2.1. Biogas technology

Biogas, one of the renewable gas energy sources, is created when organic waste is broken down by anaerobic (without oxygen) processes. The term "biogas" alludes to gas production using a biological mechanism, claims (Xu et al. 2018). According to Okrofu (2020), the generation of biogas, the by-product of anaerobic degradation, can occur naturally in the animal guts, underwater, or artificially from sealed biogas plants or landfills. Therefore, this study, views biogas from an artificial perspective in which organic materials undergo anaerobic processes in a biologically constructed system known as a digester to produce energy (Agyekum 2020). According to Bryant and Afitiri (2021), ‘biogas is produced in biogas facilities by bacterial decomposition of biomass under anaerobic circumstances’, which is consistent with this idea. Various organic materials are converted to biogas in a digester with the help of microorganisms that go through several metabolic steps (Surendra et al. 2012).

Biogas is made up of a variety of molecules, including 50-75% methane (CH_4), 30-45% carbon dioxide (CO_2), 1-2% hydrogen sulphide (H_2S), 0-1% nitrogen (N), 0-1% hydrogen (H_2), droplets of carbon monoxide (CO) and traces of oxygen (O_2), according to Akinbomi et al. (2014). However, Osei-Marfo, Awuah and de Vries (2018) point out that the substrates, the fermentation (digestion) process, and the various technical designs of the plant generally depend on the composition of the gas. This suggests that the percentage of biogas elements, as proposed by Amuna (2017), is not fixed, but depends on several variables. Regardless of these elements, the main gases produced by biogas are methane and carbon dioxide. (Zhao et al. 2021) believed that in order to effectively solve social, cultural, and environmental issues, biogas technology needed to be integrated with other systems and the environment.

2.1.1. Overview of Ghana's Energy Sector

Renewable energy sources such as biomass, hydrocarbons, hydropower, sun and wind are quite abundant in Ghana (Aboagye et al. 2021). It can also be used to make contemporary biofuels. In terms of primary energy use in 2011, 3,767 ktoe (33.3%), 772 ktoe (6.8%), 650 ktoe (5.7%), and 6,138 ktoe (54.2%) came from oil, natural gas, and wood fuels, respectively. 11,327 ktoe of energy were consumed overall, or 0.47 ktoe per person (Energy Commission, 2020). The goal of the energy sector is to create an 'Energy Economy' by the years 2022 and 2025 in order to become a significant exporter of oil and power and to ensure a consistent supply of high-quality energy services for all sectors of the Ghanaian economy (Energy Commission 2020).

2.1.1.1. Electricity

Two hydroelectric projects in Akosombo and Kpong, as well as some thermal plants, are used to generate electricity in Ghana. At the end of 2015, there were 2,140 MW of installed hydroelectric power capacity and 989.5 MW of total thermal generation capacity. 6,995 GWh of electricity were produced from hydro sources, and 3,171 GWh were produced from thermal sources (Awafo & Amenorfe 2021). The two hydroelectric facilities in Akosombo and Kpong are owned and operated by the Volta River Authority (VRA), a publicly owned energy provider. The Ghana Grid Company is the owner and operator of the transmission network.

2.1.1.2. Petroleum Fuels

The Tema Oil Refinery, the only oil refinery in the country, produces LPG along with other petroleum products, including gasoline and kerosene. Over the years, the amount of LPG produced has varied, ranging from 75,300 tonnes in 2005 to 31,600 tonnes in 2010 (Aboagye et al. 2021). Imports are used to compensate for the supply shortage. LPG use has been continuously increasing, from 45,000 tonnes in 2000 to 178,400 tonnes in 2010. The price of gasoline, gas oil, and other petroleum products increased throughout that time. However, there were some variations in kerosene usage over time (Amuna 2017).

According to a study of the intensity of energy of some sectors of the Ghanaian economy, the industrial sector consumed the most diesel fuel, followed by the services sector and the agriculture sector had a very small percentage of the total (Energy Commission of Ghana, 2020). The most frequent use for diesel fuel in industry changed depending on the sub-sector. In the mining and construction subsectors, diesel fuel was typically used to power excavators, forklifts, dump trucks and machinery for drilling, crushing, lifting, loading, and transfer to hauling vehicles. Furthermore, the services industry, particularly the transport and transport subsector, made significant use of gasoline (Ghana National Petroleum Authority 2022).

The manufacturing sector of industry's production procedures frequently employed residual fuel oil. In the food processing, alcoholic beverage, textile, iron and steel, and non-ferrous metal industries, it was primarily utilised to generate heat in machinery such as boilers and compressors. According to Cudjoe (2021), most of the wood fuels (charcoal and firewood) used in the non-household sectors were used as fuel for sawmill boilers and for businesses that make bricks, tiles, and ceramics. A smaller share of the firewood used to cook and prepare food was consumed in educational institutions and hospitals. However, small-scale restaurants and eateries were the most popular places to consume charcoal, with educational institutions making up a relatively lesser part (Narula & Reddy 2021). The use of kerosene was also restricted in all areas of the economy, in addition to hospitals and educational institutions.

2.1.1.3. Wood fuels

Most of Ghana's energy needs are satisfied by wood fuels, such as firewood and charcoal. More than 70% of the world’s main energy supply and approximately 60% of its total energy demand come from wood fuels (Arthur et al. 2018). A 20 million ton supply of primary wood fuel was expected in 2009. In 2009, 9.2 million tons of firewood and 2.2 million tons of charcoal were predicted. 90% of wood fuels are sourced directly from forests in their natural state (Kofie 2020).

The remaining 10% comes from wood waste, including new forests and logging and sawmill by-products. According to Osei-Marfo, Awuah and de Vries (2018), most of Ghana's thick wood supplies for wood fuels are found in the transition and savannah zones, particularly in Kintampo, Nkoranza, Wenchi, Afram Plains and Damongo districts. Physical evidence of reduced wood fuel resources can be seen in key charcoal making regions of Donkorkrom, Kintampo, Nkoranza, Wenchi and Damongo. As a result, in order to find wood to make charcoal, manufacturers must travel farther distances. Typically, charcoal and wood fuels are delivered from production sites (which are primarily in rural regions) to major cities and other urban centres, where they are sold to the ultimate consumers by road vendors (Weiland 2009). However, a small portion of the manufactured charcoal is shipped to West African and European markets. The majority of the wood fuel industry is run by private businesses, and there is little government control (Energy Commission of Ghana 2020). The Energy Commission's most recent regulatory change forbids the export of charcoal made from sources other than sawmill waste or specially planted forests, or sources that have not been permitted. Therefore, it is prohibited to export charcoal made from direct wood sources, such as wood taken from a natural forest.

Since July 2003, the Energy Commission has required all charcoal exporters to obtain a licence. Fischer et al. (2021) noted that an estimated 20 million tonnes of wood fuels are used each year as charcoal or as firewood, according to estimates. In Ghana, most families (about 80%) rely on wood fuels for cooking and heating water, as well as for commercial, industrial, and institutional uses. The demand for wood fuel has been increasing over the past several years.

By 2025, Ghana is expected to use more than 25 million tonnes of wood fuel, if the current trend in consumption holds. 15 million tons of wood fuel supply will come from standing stock, the remaining 10 million tons coming from regeneration or yield. This indicates that the source of wood fuel will now come from standing stock rather than from regrowth. The implication is that standing supplies will be directly depleted, increasing the rate of deforestation.

2.1.2. Biogas in Ghana

Ghana's market for biogas, a sustainable renewable energy source, is only beginning to grow (Appiah 2018). A survey conducted by Agyenim et al. (2020) found out that the Ghanaian renewable energy sector is appealing to foreign businesses from the sector interested in investing in Sub-Saharan Africa because of its economic growth and development of the regulatory environment. Due to the current energy situation, which is characterised by grid instability and rising energy costs, commercial and industrial producers from the agricultural industries are looking for alternative solutions to secure a steady supply of energy to prevent production loss and lower energy costs. One of the most attractive ideas is to build biogas plants at the production sites. It allows farmers to simultaneously dispose of agricultural waste, produce electricity for self-use, use residues as fertilisers, and feed energy surpluses into the grid. The type of biodigester Ghanaians use most frequently is the fixed dome biodigester (FDBD), which is fashioned after a local drinking pot (Aboagye et al. 2021). FDBDs are effective in converting organic waste to biogas and biofertilizer, but are expensive and difficult to construct. Small burnt bricks are used for construction, which requires highly specialised labour that can occasionally be difficult to find.

Additionally, because all FDBD are underground, it is very difficult to find leaks and fix them when they do occur. These issues, among others, served as inspiration for the Institute of Industrial Research (CSIR-IIR), a division of the Ghanaian Council for Scientific and Industrial Research (CSIR), to conduct research and create substitute designs that are significantly more efficient than dome biodigesters in producing high quality biogas and bio-fertilizer and easier to build and maintain. The development of novel bio-digester technologies has frequently been hindered by funding constraints, but over the past 10 years, CSIR-IIR has added three additional designs to the traditional FDBD. Anaerobic Baffled Bio-Digester (ABBD), a brand new biodigester that CSIR-IIR designed and constructed in 2014, addressed the cost and construction-related problems of FDBDs. The design and construction of ABBD resemble a regular septic tank but have all the advantages of a biodigester when constructed from local resources such as sandcrete blocks, cement, and sand. Baffles in the digester control the flow of digestate within the digester to enhance mixing of the substrate for optimum biogas generation (Bensah, Antwi & Ahiekpor 2010).

With this creative design, biogas production and waste treatment both work extremely well. The Portable Anaerobic Baffled Bio-Digester (PABBD) was created in 2019 for the production of biogas and the treatment of small amounts of home wastewater.

The CSIR-IIR created and constructed the Integrated Bio-digester most recently in 2020. (IBD). The development of the IBD was assisted by the GCRF-EPSRC Global Research Translation Award-funded ACTUATE project, which is linked to the GCRF-funded RECIRCULATE project. This was planned and constructed as the IBD to address concerns about FDBDs, including as construction costs and the location and repair of digester leaks. Dusastre and Martiradonna (2020) emphasized that the concept for IBD was first generated during a brainstorming session by the ACTUATE team of researchers from Lancaster University and the CSIR. From a simple hand sketch of the digester system and a thorough scientific analysis of the digester system, we moved to actual engineering design and then construction. The integrated bio-digester is unique since it was constructed to fit into the tiny footprint of the school and utilises local resources. Food waste from students' homes and human waste from the school's septic tank are the two organic waste streams that are used as feedstock. The digester may produce biogas and bio-fertilizer by pumping waste from the school's septic tank and the food waste mixing tank into it with the assistance of two macerator pumps and an on-site solar power system. The gas powers the ‘display lab’, which teaches how to use biogas for cooking and lighting. The school uses the bio-fertilizer to improve and ‘green’ its surrounds.

2.1.3. Biogas production

The typical composition of biogas is 55-80% methane (CH_4), 20-40% carbon dioxide (CO_2), and trace gases including nitrous oxide and poisonous hydrogen sulphide. Methane gas is particularly significant since it can be utilised to produce energy due to its high energy content. Deublein and Steinhauser (2008) averred that methane contributes to climate change 21 times more than carbon dioxide does. It makes sense to trap and burn the methane produced by natural putrefaction rather than allowing it to escape into the atmosphere. Methane is converted into heat and carbon dioxide during combustion. By doing this, one may harness the gas's energy and reduce the effect it has on climate change.

Anaerobic digestion produces biogas when bacteria digest (eat) organic materials without the presence of oxygen (or oxygen). Methane (CH_4) and carbon dioxide (CO_2) make up the majority of biogas, with very trace amounts of other gases and water vapor (Lybaek & Kjaer 2022). Carbon dioxide and other gases can be eliminated, leaving only methane. Natural gas consists of methane. Anaerobic digestion results in the production of biogas. Biogas is a versatile renewable energy source and has several applications. Across the Ghana, businesses and communities use biogas to:

I. Power engines, produce mechanical power, heat and/or electricity (including combined heat and power systems)
II. Fuel boilers and furnaces, heating digesters and other spaces;
III. Run alternative-fuel vehicles; and
IV. Supply homes and business through the natural gas pipeline

The quality of the biogas determines how it is used effectively. Osei-Marfo et al. (2018) advised that to remove carbon dioxide, water vapor, and other small impurities, biogas is frequently cleaned. The energy value of biogas is increases when these chemicals are removed. Generally, harsher, less effective engines such as internal combustion engines employ low-quality biogas. Engines that are more sensitive but also more efficient can utilise higher grade biogas that has been cleared of trace contaminants. Biogas that has been processed to meet pipeline quality requirements can be supplied through the natural gas pipeline and used in residences and commercial buildings. Additionally, compressed natural gas (CNG) or liquefied natural gas can be made from biogas by cleaning it and upgrading it (LNG). Vehicles and trucks can be fuelled by CNG and LNG.

Sub Chapter Two

2.2.1. Theoretical Framework

This session presents the theoretical framework and the most pertinent theoretical sources for the examination of the research question. Sustainable development, the availability of sustainable energy, the green economy, strategy, and the definition of terminology are some of the theoretical ideas covered.

2.2.1.1. Sustainable Energy Access in Sub-Sahara Africa

Sub-Saharan African nations are anticipated to generate and use more energy over the next ten (10) years in order to support economic growth. According to Okrofu (2019), despite the abundant energy resources in the region, its electrification rates are still low. One of the most limiting development hurdles is the 15% rural electrification rate and the 30-40% national rate. Furthermore, the populations of most countries growing faster than their connection rates, which is not promising for increasing electrification rates (Bugaje 2018). Given the current situation and available funds, energy planning in Sub-Saharan Africa should concentrate on autonomous, ecologically responsible energy policies that maximize investment returns and foster economic growth (Weisser 2004). Ahiataku-Togobo and Yaw Owusu-Obeng (2016) advised that for the region's economy to prosper, strategies that reduce the cost of electrification-particularly household connection costs are essential. Insufficient access to energy services continues to be a significant obstacle to sustainable development despite the general consensus that the provision of inexpensive, dependable, and socially conventional energy services is a requirement for meeting the Millennium Development Goals (Brew Hammond et al. 2009).

According to Bryant and Afitiri (2021) energy planning in Sub-Saharan Africa should focus on independent and environmentally sound energy policies that fully utilize the benefit of investment and support economic growth given current circumstances and financial restrictions. For the region's economy to prosper, strategies that reduce the cost of electrification, particularly household connection costs are essential. Insufficient access to energy services continues to be a significant obstacle to sustainable development despite the general consensus that the provision of inexpensive, dependable, and socially conventional energy services is a requirement for meeting the Sustainable Development Goals (Brew Hammond et al. 2009).

2.2.1.2. Green Economy

The term ‘green economy’ is used in a variety of settings and has numerous definitions (World Bank 2016). In 2011 the United Nations indicated that, using the green economy as a tool, the world can achieve both sustainable development and economic expansion. The idea was one of the key themes of the Rio+20 summit in 2012, which sparked a boom in research and writing aimed at defining and explaining the green economy on a global scale (UN Sustainable Development Knowledge Platform 2015a).

2.2.1.3. Renewable Energy Sources and Sustainability

Bioenergy, hydropower, geothermal, solar, wind, and ocean (tide and wave) energy are examples of renewable energy sources that replenish themselves naturally without depleting the planet. Sustainable energy is described by Energypedia (2020) as ‘a dynamic equilibrium between the fair availability of products and services that consume a lot of energy to all people and preservation of the earth for future generations’.

The continued use of fossil fuel-based energy sources (coal, oil and gas) due to growing global energy demand and the increasing population became problematic because it brought about a number of problems including depletion of fossil fuel reserves, greenhouse gas emissions and other environmental concerns, geopolitical and military conflicts, and ongoing fuel price fluctuations (Lybaek & Kjaer 2022). These issues will eventually result in unsustainable conditions that could pose an irrevocable threat to human societies (Baloch et al. 2019). However, renewable energy sources are the best alternative and the only way to address the pressing problems (Arthur et al. 2018).

2.2.2. Evolution of Biogas Technology in Ghana

According to Brew-Hammond and Kemausuor (2009) three (3) stages can be used to analyse the development of biogas technology in Ghana. These are the experimental stage, the adoption stage and the current stage.

2.2.2.1. The stage of experimentation or trial

Although, Ghana has historically been interested in and aware of biogas systems since the 1960s, this interest did not really take off until the middle of the 1980s (Arthur et al. 2011). According to Bensah et al. (2010), before the 1980s, biogas facilities were established to supply residential energy for cooking. However, due to outdated technology, many of these biogas systems failed soon after they were installed. The first biogas plants were built at Appolonia in 1986, claim Arthur et al. 2011; Brew-Hammond, and Bensah 2010. The facilities, which were 10 m3 Chinese fixed dome digesters, were set up by the Ghanaian government's Energy Ministry with assistance from China (Arthur et al. 2011).

These biogas plants were built on a cattle ranch so that the plant'' feedstock, cow dung, could be used there. The biogas technology was chosen as an alternative to cooking fuels and as a way to reduce deforestation and the associated environmental problems (Arthur et al. 2011). However, the biogas technology took a nose dive from government involvement possibly because the government did not understand or appreciate the demand of the technology or a deeper and collaborative stakeholder engagement was not properly done leading to feedstock challenges for the digesters. Arthur et al. (2011) argued that the plant does not function at full capacity due to lack of feedstock materials. Awafo and Amenorfe (2021) asserted that although the operation of a bio-digester may appear straightforward, daily maintenance for the greatest benefits may be difficult to achieve in light of the high failure rate of biogas facilities in poor nations. This is due to the fact that the digester needs continuous and continuous feeding in addition to making sure that the feedstock is evenly mixed and that the ideal conditions for acidity, alkalinity, C/N ratios, temperature, and performance are met. This causes theoretical and practical gaps that hinder the adoption and use of the technology, particularly in Ghana.

2.2.2.2. The Adoption Stage

From the 1990s to 2012, the government distanced itself from any involvement in biogas technology (Arthur et al. 2011). Installation of some biogas plants in some hospitals, particularly Battor, Akwatia and Nkawkaw hospitals, which are still primarily used as sewage treatment facilities, was made possible with the help of the Catholic Secretariat and the German Agency for Technical Assistance (GTZ). Additionally, GTZ helped install additional biogas plants at Ejura slaughterhouses, the Animal Science Department of the Kwame Nkrumah University of Science and Technology (KNUST), the Accra Psychiatric Hospital, and other locations while providing training to some technicians as part of building local capacity (Bensah et al. 2010). From 2000 until 2012, commercial firms like Biogas Engineering Ltd (BEL), Biogas Technology Africa Limited (BTAL), Beta Civil Engineering Limited (BCEL), Impact Environmental (IE), and others were in charge of the promotion, design, and installation of biogas facilities. Despite the various obstacles, their fervour and commitment for the biogas technology allowed them to hold down the fort in Ghana and keep the technology current (Bensah et al. 2010).

2.2.2.3. The Current State

The Ghanaian government has renewed its interest in promoting biogas technology as in the SE4ALL 2012 document, which outlined the government's intention to build more than 200 biogas plants in educational institutions throughout the country. To achieve this objective, the government built ten (10) biogas facilities in several schools in the Greater Accra Region (Dusastre & Martiradonn 2017). Except for one institution (St John’s Grammar) where the equipment was finished and installed for all except the electricity are left unfinished. Three other private SHSs have also been set up. As a result of the huge advantages of the technology, biogas plants can operate independently primarily to meet their energy and sanitation needs. In addition, the Ghana Electoral Commission and the Environmental Protection Agency worked with biogas installers to create BAG, which was introduced at the EC in 2018.

2.2.3. Pros and Cons of Biogas technology in Ghana

2.2.3.1. Pros of Biogas Technology

The first and most crucial aspect of biogas is that it is a financially viable method for converting biomass because the raw materials required for its production are very inexpensive, practically free, and it also generates cash (Energy Commission 2020). The key ingredients or raw material utilised for biogas production are waste material from kitchens (both solid and liquid), animal waste from different farms (cattle farm, pig farm, poultry farm), waste water sludge, and waste material from food processing companies. In addition to this, landfills also produce biogas (Damrongsak et al. 2017). The component of biogas that carries energy is methane. The calibre of the raw materials utilised to produce biogas determines its quantity and composition. A gas produced from a landfill will not be as rich in methane as one produced from a cleaner raw material, such as kitchen garbage or organic household waste macerated in a closed container or chamber (Nahar et al. 2017). Biogas combustion produces a smaller and less harmful subset of pollutants in addition to carbon dioxide, making it a cleaner fuel compared to other energy systems or fuels (particularly fossil fuels). By eliminating the use of firewood and synthetic fertilisers, which have a negative impact on soil health and fertility and have a carbon footprint, the use of biogas can help reduce deforestation. When bio-CNG is used, it creates about 22g CO_2/MJ of carbon dioxide, which is 80% less than when fuels based on petroleum are burned. During combustion, fossil fuels emit toxic and harmful aromatic and polyaromatic hydrocarbons; however, biogas combustion does not produce these emissions.

The main emission of soot and matter from the burring process is prevented as a result of the absence of hydrocarbons. Soot production during natural or biogas combustion depends only on the conditions under which gas combustion control, which is challenging to perform with liquid fuels, can be used to ignore the net release of soot (Nahar et al. 2017). The digestate or slurry from biogas plants may act as a pesticide. Without the harmful side effects of synthetic pesticides, it can control some pests (Wang et al. 2018). In 2010, research at the University of Tamil Nadu in Coimbatore, India, revealed that biogas slurry has the potential to operate as a pesticide; it effectively shields tomatoes from worm attacks. The nematode population in the soil and the intensity of the action decreased due to the biogas slurry applied to the tomato leaves and added close to the root. Additionally, tomatoes are producing more and growing more vegetatively (Nahar et al. 2017). Enriched organic waste is a byproduct of biogas generation (Bio-fertilizer). This will be thought of as a good substitute for chemical fertilizers and has the capacity to reduce erosion (Mittal et al. 2017). The impact of greenhouse gases is considerably reduced by biogas plants; These facilities generate less methane and trap harmful greenhouse gases, which they then use as fuel. Biogas production contributes to a decrease in the use of fossil fuels such as coal and oil (Damrongsak et al. 2017).

Another significant benefit of biogas is that all of the processes involved in its creation take place naturally and do not require any energy. Furthermore, as trees and crops continue to grow, the raw materials needed to produce biogas are renewable. Food waste, manure, sewage waste, and the constant availability of farms all contribute to its high sustainability. Overflowing landfills released a terrible odour throughout the neighbourhood and allowed hazardous liquids to seep into groundwater.

The production of biogas contributes to better water quality (Weiland 2009). Waterborne infections will become less common as a result of anaerobic digestion's ability to inactivate germs and parasites. Biogas production also facilitates effective waste management and garbage collection, which automatically improves the quality of water and soil (Kadam et al. 2017). For developing communities, biogas also provides a healthier cooking environment. The use of firewood for cooking has a negative impact on the health of women and children in many places and countries. The entire family is protected from the kitchen smoke thanks to the gas burner. By doing this, the family is protected from fatal respiratory illnesses. Due to the lack of safe cooking fuels, 4.3 million people around the world die at the start of each year from illnesses related to indoor air pollution (Agyekum 2020).

Biogas production is believed to be a straightforward process (Nahar et al. 2017; Abadia et al. 2016). The small-scale biogas generation process is relatively simple to set up, requires very little capital, and simply uses household trash as a raw source. Because the biogas generated by digesters can be used to generate electricity and prepare food, it has a low production cost. The same technique and procedure used in the home to produce biogas can also be applied on farms. An entire days’ worth of biogas may be produced from a cow's waste, which is sufficient to power a 100-watt lamp. Biogas can be compressed to produce natural gas-quality fuel, which will provide many green jobs and have a favourable impact on the economy of a nation (Lindkvist et al. 2017)

2.2.3.2. Cons of Biogas Technology

According to Osei-Marfo et al. (2018) the procedures used to manufacture biogas as well as the actual biogas itself have various drawbacks.

One of the main complaints regarding biogas production is that the technology employed is ineffective and unable to generate enough biogas for a large population (Głowacka et al. 2020). Many governments are reluctant to invest in this industry. Biogas has certain contaminants after compression and refining. Metal components of an automobile engine will rust because of these biogases. The gaseous mixture is more suitable for lighting and stoves in kitchens (Sorathia et al. 2012).

Another element that negatively impacts biogas generation is temperature. About 37 C is required for waste bacteria for optimal digestion. Digesters in areas with cold climates require adequate heat energy to ensure a steady flow of biogas. Furthermore, because industrial biogas production requires an abundant supply of raw materials, rural and suburban areas are suitable locations for it (Sorathia et al. 2012).

Sub Chapter three

2.3. Renewable energy in Ghana

As already indicated, Ghana has begun to engage in renewable energy, but at a modest pace (Energy Commission 2020). In addition to the Bui, Kpong, and Akosombo Dams in Ghana, the country’s first solar power plant launched in May 2013 in Navrongo in the Upper East Region. The Volta River Authority spent almost $8 million on the Navrongo Solar Power Plant. There have already been reports that the plant is inefficient. Both energy storage and energy delivery to homes have encountered issues (GRIDCo 2019).

The Pwalugu Multipurpose Hydropower Dam, located in Ghana’s Upper East on the White River, is another significant investment proposed. Construction of this project begun in 2017 and was expected to be completed in 2022.

Pwalugu Dam is considered a multipurpose dam for a number of reasons, including the objective goal of generating power and the secondary objective of flood management. Numerous employment opportunities will be created, as envisaged during the dam's construction and operation. However, it will also have an impact on the surrounding area through traffic noise, dust, and exhaust pollution. The Volta River Authority intends to consult the public and create awareness of the project, its advantages, and its effects in order to prevent many people from feeling threatened and being forced to relocate. It must be emphasised that whether renewable energy will be successful in Ghana is a contentious issue.

However, many measures are being taken, and since renewable energy comes from an endless source, employing it would result in lower electricity and heating costs. Furthermore, to become cheaper, electricity would be supplied more often than it is now (GRIDCo 2019). Although it is a costly investment for the government and the investors' businesses, it is feasible due to the financial backing of industrialised nations. Ghana also uses solar street lighting in some regions, which is considered a step toward making the country more environmentally friendly (Ministry of Energy and Petroleum 2020).

Therefore, a number of nations donate to or support foreign governments in finance and training to take the step towards an eco-friendly atmosphere in order to promote and invest in renewable energy resources and protect our climate. Germany is a significant investor in Ghana. After the Renewable Energy Act was ratified in 2011, Germany increased its support for Ghana's energy industry by 1.8 million euros through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Ministry of Energy and Petroleum 2013). The regular financial investment in biogas initiatives and climate change opportunities strengthens the German-Ghanaian bonds (Mittal & Risco-Martin 2017). It is vital to note that without awareness campaigns and projects, financial support and investment alone would not be able to protect the environment and improve the climate in Ghana. According to Narula and Reddy (2016) people must be aware of the long-term dangers of fossil fuels and the need for a gradual transition to renewable energy sources.

2.3.1. Challenges to the Development of Renewable Energy in Ghana

This part presents some of the challenges Ghana faces in the development of her renewable energy.

2.3.1.1. Limited Sources of Renewable Energy

Okrofu (2019) noted that small and mini-micro hydro, wind, solar, biomass, and municipal solid waste are the only renewable energy sources in Ghana that can generate between 380 and 500 MW and deliver competitively between 2,500 and 3,500 GWh. By 2023, this will account for almost a tenth of Ghana's energy needs. Obeng-Darko (2019) argued that the cost of generation would increase drastically if there were more than 10% renewable energy in the energy mix. The potential of generating grid electricity from solar PV is limited by capital rather than resource. Wind may have the largest development capacity among the options and has the potential to contribute significantly to grid power by about 200300 MW producing 600 GWh (GRIDCo 2019).

2.3.1.2. Cost per Kilowatt Hour

The cost per unit to customers when compared to energy from other sources is one of the major obstacles to the adoption of renewable energy sources (fossil fuels). In comparison to $0.04/kWh, the cost of grid-connected solar energy is above $0.30/kWh. In Ghana, a solar panel facility costs around US$ 7000/kW, but a gas-fired thermal power station costs between US$500 and US$1000 (Lybaek & Kjaer 2022).

2.3.1.3. Investment Risk

The danger of investing in renewable energy installations is increased by the erratic pricing of oil and gas on the global market. A decline in hydrocarbon prices dampens interest in investing in the field of renewable energy (Nahar et al. 2017).

2.3.1.4. Competing Technologies

Within the subsectors of the renewable energy industry, there is a fierce battle for predominance (Arthur et al. 2018). In the field of biofuels, proponents of cellulose, ethanol, and biodiesel compete with those who want a solution based on corn. Concentrating solar power technologies compete with the considerably more widely used photovoltaic systems in the solar market.

2.3.1.4. Not in My Backyard Syndrome

Although renewable energy provides less pollution compared to fossil fuel energy, there have been significant backlash from communities regarding the construction of facilities to produce renewable energy**.** Many Ghanaians do not want the construction of biogas plant within their neighbourhood due to misconception about the by-product of biogas (Aboagye et al. 2021).

2.3.1.5. Constraints to Biofuel Development

Policy directives and strategies are necessary for the creation of an alternative to current fuel. Primary limitations include the availability of feedstock, local processing capacity, technology advances related to end use, customer acceptance of new fuel, and cost competitiveness (Sorathia et al. 2012).

2.3.1. 6. Feedstock for Bio-fuel Production

In various countries, different feed stocks are used to produce biofuels. The overall trend is for nations to select feedstock plants that are currently cultivated locally on large scales and that have other commercial value outside producing fuel. Sugar cane, and palm oil all have considerable benefits for the manufacture of biofuels in Ghana (Damrongsak et al. 2017).

2.3.1.7. Cost Competitiveness of Biofuel

The global market for biofuels is underdeveloped, and even at $73.00 per barrel for crude oil, biofuels cannot compete. Political factors and tax breaks influence the worldwide biofuel business (Energypedia 2020). Renewable energy sources can be used to support and amplify the supply of conventional energy. However, enormous financial, technological, and psychological obstacles must be overcome before any meaningful penetration can be achieved (Smeets et al. 2007).

2.3.2. Factors that influence Biogas Adoption in Ghana

About 15% of Ghana's population relies on biogas for their cooking energy needs, including fuel wood, charcoal, crop by-products, and animal dung (Energy Commission 2020). Biogas accounts for over 20% of domestic energy usage at the Ghanaian household level. In conventional cook stoves, the direct burning of biomass results in the production of numerous gases, including carbon monoxide, hydrocarbons, and particulates. This is supported by the assertion of Awafo and Amenorf (2021) that cooking in Ghana is typically done in poorly ventilated spaces, which contributes to a significant number of serious illnesses due indoor air pollution (IAP). This claim was supported by Lambe et al. (2015) and Surrendra et al. (2011), who also noted that there is sufficient evidence to link solid fuels to the occurrence of diseases such as child pneumonia, chronic obstructive pulmonary diseases, and lung cancer in developing nations like Ghana due to IAP. According to the World Health

Organization (WHO 2018), IAP from the use of solid fuels is responsible for roughly 1.5 million pre-mature deaths annually. Out of the 1.5 million deaths, 1.3 million (or 85%) are directly attributable to the use of biomass, with the remaining deaths coming from the use of coal. Since they actively participate in cooking with traditional biomass, inhaling the smoke frequently, women and children experience IAP at a higher rate (Lambe et al. 2015).

Exposures to IAP exposures may be to blame for Ghana's high prevalence of health issues like asthma and cataracts, low birth weight and stillbirth, tuberculosis and high blood pressure.

Unlike firewood, dried cow dung, and agricultural residues, biogas produces a clean, smokefree environment (Surrendra et al. 2011). The biogas system has been in use in Ghana for a while, albeit slowly, but technological advancement is required to increase energy production, particularly for institutions. The usage of biogas in Ghana can considerably reduce IAP and cure diseases caused by IAP. Additionally, because biogas technology forces people and organizations to build toilets, it could end the problem of open defecation, which is pervasive in Ghana. Cholera, typhoid, dysentery, and other water-borne diseases are all consequences of open defecation. This was confirmed when UNICEF reported on November 19, 2015, that open defecation is widespread in Ghana and is a major cause of the country's high rates of diarrhoea, the spread of intestinal parasites, and undernourishment. According to Scarlat, Dallemand and Fahl (2018) a myriad of factors influence the adoption of biogas in Ghana. These include the following:

2.3.2.1. Environmental benefits

Biogas has a lot of environmental benefits. Due to the lack of landfills or not built landfills it is difficult for most African countries to dispose of municipal solid waste (MSW), especially the organic component. This has an impact on environmental best practices. Wood resources in Ghana have been significantly impacted by its use for cooking and heating. To protect forest resources and restore the ecology, this calls for technologies like a biogas system that can replace wood fuel (Surrendra et al. 2011).

A properly designed and installed biogas digester, according to Brown (2006), has a number of advantages, including improving sanitation, reducing greenhouse gas emissions, reducing demand for wood and charcoal for cooking, and helping preserve forested areas and natural vegetation, as well as providing high-quality organic fertilizer. Van der Gaast et al. (2009) asserts that the availability of biogas as a substitute for wood fuel to meet Pakistan's energy needs, particularly home energy for cooking and heating, has slowed the rate of environmental degradation and deforestation. According to Berhe et al. (2017), biogas systems have the potential to be a low-cost energy source that does not require the gathering wood for fuel, reduces the destruction of native forests, reduces GHG emissions into the air and increases the carbon sequestration of native forest trees. This was validated by Kelebe and Olorunnisol (2016), who reported that switching from firewood to biogas resulted in a 50-60% reduction in firewood usage in 12 rural homes. Furthermore, they claimed that by 2014, Ethiopia had 9,577 residential biogas installations, saving approximately 2,873 acres of forest area. According to Minde et al. (2013), burning 1 kilogram of wood in a typical cookstove produces roughly 318 grams of carbon. However, if biogas is used, each household annually saves the consumption of 576 kg (1,270 kg) of cow dung and 3metric tons (6600 pounds) of firewood. Consequently, if biogas is used, the global warming potential (GWP) of GHGs will be reduced by roughly 70% to 85% (Berhe et al. 2017). Biogas technology can combat environmental challenges such as eutrophication, acidification, air pollution, spread of diseases and climate change issues.

2.3.2.2. Social benefits

Osei-Marfo et al (2018) contended that women and children are primarily responsible for meeting energy needs in terms of obtaining the wood fuel needed for residential usage, as they must travel great distances to do so. Since the loads are typically very heavy, this takes a lot of time and is also physically demanding. Due to the fact that women and children, particularly girls, are frequently sacrificed on the altar of tradition and custom in many Sub-Saharan African nations, this practice deprived them the chance to receive an education. Biomass burning releases pollutants like carbon monoxide, methane, nitrogen oxides, benzene, formaldehyde, benzopyrene, aromatics, and particulate matter that cause significant harm to women and children because they are more susceptible to long-term exposure, according to studies by Lambe et al. 2015; Minde et al. 2013 & Fullerton et al. 2008. Smokeless biogas would be a great replacement for use in underdeveloped nations, particularly Ghana, to improve the well-being of women and children. The time saved from the harvest of fuelwood can be put to good use and provide women with the opportunity to attend school.

2.3.2.3. Economic benefits

Fresh manure, which produces less nitrogen than this amount, is projected to generate less than 0.5 kg of nitrogen compared to bio slurry from biogas facilities. The return on investment of the method can be realised in three to four years if bio slurry is treated like manure. This is because the use of bio slurry can save up to 19 kg of phosphorus, 39 kg of nitrogen, and 39 kg of potassium, which can help alleviate the problem of soil degradation and reduce the reliance on artificial fertilisers, as mentioned by Minde et al. (2013). Many jobs in carpentry, masonry, and plumbing will be created if biogas technology is widely implemented for institutional use.

2.3.3. Policies and Strategies for Renewable Energy Promotion

The goal of the government is to foster an environment that will encourage private investment in initiatives involving renewable energy (GRIDCo 2017).

The 'Regulated Market', which allows private parties to launch and develop renewable energy projects as independent power producers, is distinguished from the development of utility-led projects. In this area, VRA is the utility that is most in use. By 2023, the Ghanaian government plans to generate 30% of its energy from renewable sources. The Energy Commission Act of 1997, the Public Utilities Regulatory Commission Act, and the Renewable Energy Act govern renewable energy laws in Ghana. The Energy Commission’s Renewable Energy Division is in charge of creating strategies and policies, such as the Renewable Energy Act, which covers all Renewable Energy technologies, including wind, solar, hydro, waste-to-energy, and biomass.

2.3.3.1. Main Actors

The Ministry of Energy, which is in charge of the National Gas Company and the National Petroleum Company, is one of the primary players in addition to the utilities. These organizations mostly work with energy derived from fossil fuels like oil and gas. Regulatory organizations are also crucial for renewable energy: The Public Utilities Regulatory

Commission (PURC) was created to control and monitor the public sector's delivery of utility services to consumers and associated issues. Its responsibility is to balance the interests of both producers and consumers while setting feed-in prices for the delivery of power to the grid.

The Ghanaian government formed the Energy Commission (EC) to oversee and manage the country's use of its energy resources. Energy Commission is in charge of creating and revising national energy plans as well as, among other things, ensuring the participation of the private sector (GRIDCo 2017).

The Energy Commission is the last legal entity that must grant licenses for renewable energy businesses in Ghana. The Environmental Protection Agency (EPA) and the Ghana Standards Board are two more regulatory organizations that are involved in the renewable energy sector. These organizations, respectively, grant environmental licenses and certification for equipment for import and distribution in Ghana. However, specific projects like municipal waste-to-energy also need approval from the regional regulatory organizations in charge of overseeing waste management, such the Accra Metropolitan Authority and Kumasi Metropolitan Authority.

2.3.3.2. The Regulatory Framework

For investments in the renewable energy sector, the following incentives are available: Import taxes on Renewable Energy equipment should be waived, and norms and standards for solar, wind, and bioenergy systems should be developed. There are rules and procedures in place to guarantee that all Renewable Energy service providers receive licenses, permits, and Purchase Agreements for Power. Recently, clear Feed-in Tariffs (FITs) for electricity produced by Independent Power Producers (IPPs) and renewable sources were released.

Obeng-Darko (2019) argued that despite local and international financial incentives, the regulatory environment and established practices pose obstacles that limit the use of renewable resources in both grid-connected and off-grid applications. The commitment of the government to a comprehensive strategy and the cooperation of various stakeholders to investigate viable alternatives are both necessary to overcome these impediments. International help in the form of funding, technical support, and capacity building can supplement such action but cannot replace it. The experience of Ghana indicates that such a strategy for energy efficiency measures can be somewhat successful, but it also emphasizes the significance of domestic and international structures that guarantee the longevity of an institution with enough resources for project and program execution.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the approach and techniques adopted to achieve the objectives of the study. The chapter looks at the research methods, design, data collection methods and instruments, as well as other issues pertaining to research methodology. The chapter ended with a discussion of the difficulties faced throughout the data collection process.

3.1. Research Methods

Bryman (2008) noted "All research is based on some underlying philosophical assumptions about what constitutes 'valid' research and which research method(s) is/are appropriate for the development of knowledge in a given study". According to Moser and Korstjens (2018) research is one of the ways through which people find solution(s) to social problems; and methodology is the choice we make about the cases to study, and methods of data gathering, and other forms of data analysis, in planning and executing a research study.

The study adopted the mixed method. The mixed method allows triangulation of both qualitative and quantitative research strategies to elicit relevant information from the research participants. Bryman (2004) is of the view that the methods of quantitative and qualitative approaches can complement each other in a single study of social phenomena. On this premise, Grix (2018) has advised that it is generally a good idea for social scientists to use more than one method of enquiry to improve the chances of getting better, more reliable data and to minimize the chances of biased findings. The mixed method was chosen because the combination of qualitative and quantitative methods allowed the researcher to cross-check the data collected by different methods, thus, making the results of the study valid and credible.

3.2. Research design

In the words of Myers, Well and Lorch (2013) research design is the blueprint for conducting a study that maximises control over factors that could interfere with the validity of the findings. According to them, designing a study helps the researcher to plan and implement the study in a way that will help the researcher to obtain intended results, thus increasing the chances of obtaining information that could be associated with the real situation. Similarly, Denscombe (2014) claimed that a research design is a master plan that outline the method and procedure for collecting and analysing the needed information.

The design that was adopted for this research is the concurrent mixed method. The considerations that warranted the adoption of this design include the nature of the research questions, the data required to answer them and the philosophical assumptions underlying the entire research. The design uses pluralistic methods of data collection and analysis to produce knowledge about the problem. The rationale is that “a complete picture could not be generated by any one method alone” (Bryman et al. 2008). In concurrent mixed methods, two or more methods are used to confirm, cross-validate, or corroborate findings within a study (Creswell 2009).

3.3. Sampling

Sampling is the use of definite procedures in the selection of a part for the express purpose of obtaining from its description or estimates certain properties and characteristics of the whole (Kumekpor 2002).

It involves a careful examination and selection of the units of a phenomenon to study. A sample of 100 individuals two individuals each from and 5 organisations was selected for the study. The multistage sampling technique was employed for the selection of the sample. It was based on the simple random and purposive sampling techniques. According to Amedahe (2002) simple random sampling is appropriate when a population of study is similar in characteristics of interest. The simple random technique was used because it gave all units of the target population equal chances of being selected. The random sampling technique was used to select 100 individuals within the region, while the purposive sampling was used to select the five (5) organisations. According to Creswell (2017) purposive sampling means that participants are selected because they are likely to generate key information on the topic under study. Simply put, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience.

3.4. Data collection instruments

The study relied on both primary and secondary data. The instruments that were used in the data collection were questionnaires and interview-guide. The questionnaire consisted of both opened and closed-ended questions while the interview-guide was made up of semi structured questions. This decision was influenced by the assertion of Yin (2017) that closed and open-ended and flexible questions are likely to get more detailed responses; and therefore, provide better access to interviewees' views, understandings, experiences, perceptions and interpretations of events.

3.5. Data collection methods

Data collection method in the wider sense connotes the manner in which primary data is gathered for the purposes of analysis (Stake 2006). Having considered the research questions and the purpose of the study it became apparent that questionnaire and interview were most appropriate for the generation of the primary data.

3.5.1. Interview

Merriam and Grenier (2013) defined interview as a controlled situation in which one person, the interviewer poses a series of questions to another person, the respondent (p. 13). Some instances in which the use of interview could be efficient include the need-to-know what people are thinking and, the need to explore the reasons and motivations for the attitudes and opinions of people. The interview was semi-structured. In this regard, more or less open and closed ended questions were brought to the interview situation in the form of an interview-guide. The rational for the choice of the semi-structured interview was to gain an understanding based on textual information obtained; and also, the level of depth of understanding that the researcher intended to pursue. Based on the objectives set for the study and guided by Bryman's advice, interview schedules were developed for the participants in order to address issues specific to their individual understanding of biogas as alternative source of renewable energy in Ghana. In all cases, the interview schedules were semi-structured so as to allow the respondents some latitude to pursue what they considered relevant while making sure that the researcher's own questions were adequately answered.

3.5.2. Administering the Questionnaire

Attempts were made to achieve some kind of spatial representation of the respondents selected within the Central Region of Ghana. The survey was carried out with the help of two field assistants. The questionnaire was pre-tested in the study area a month before the actual data collection. Lebow et al. (2012) opined that it is always acceptable to pre-test a questionnaire before administering to eliminate ambiguities and errors in data collection and to ascertain the validity and reliability of the instruments. It was to find out from respondents how long it took them to complete the questionnaires; whether the instructions and items were clearly understood (Bell 2005). Feedback received was used to improve the instrument by making the right corrections and adjustments in the final write-up to increase the level of validity. The pilot test lasted for only a week. The actual administration of the questionnaires lasted for nearly a month.

3.6. Member Checking

In order to reduce the potential for researcher bias and ensure the exactness of the data gathered during the interview, I did a member check. Birt et al. (2016) were of the view that the trustworthiness of results is the bedrock of high quality qualitative research. Member checking, also known as participant or respondent validation, is a technique to explore the credibility of results. Member checking is defined as the sharing of interview transcripts, analytical thoughts, and/or drafts of the final report with research participants to make sure they and their ideas were being represented accurately (Patton 2002, p.21).

Birt et al. (2016) also viewed member checking as the method of returning an interview or analysed data to a participant for purposes of data clarification (p. 16). In member checking, data or results are returned to participants to verify accuracy and resonance with their experiences. Member checking is used to validate, verify, or assess the trustworthiness of qualitative results (Doyle 2007, p. 78). The interviews were conducted in English. All interviews were transcribed personally by the researcher to ensure that no data were lost. In some cases, during the transcription, the researcher identified some vagueness and gaps. Some of the interviewees were contacted again via phone calls to clarify or deepen their responses. Clarification and confirmation of the issues and themes that were raised during the interview were obtained.

3.7. Validity and Reliability of Instruments

Reliability according to Creswell and Hirose (2019) is the extent to which a research instrument yields similar results whenever it is employed to elicit data under constant conditions while validity refers to the extent to which the research instrument records what it is intended to record (p. 67). Face and content validity was used to ensure validity of the instrument. The validity of the questionnaire was ascertained by discussing the questionnaire items with my classmates before passing them on to my supervisor for further evaluation and consideration before use. My supervisor assessed the face and content validity to see whether the instrument has measured what it appears to measure. The reliability of the questionnaire was determined through the internal consistency of the items in which Crobach's alpha coefficients were calculated and the results revealed. Coefficients of <0.76 indicated that the instruments were reliable (Yin 2017).

3.8. Trustworthiness

The trustworthiness of results is the bedrock of high quality qualitative research (Shenton 2014). According to Rourke and Anderson (2004) demonstration of the trustworthiness of data collection is one aspect that supports a researcher’s ultimate argument concerning the trustworthiness of a study. The aim of trustworthiness in a qualitative inquiry is to support the argument that the inquiry’s findings are “worth paying attention to” (Birth et al. 2016). Lincoln and Guba (1985) have proposed four alternatives for assessing the trustworthiness of qualitative research, that is, credibility, dependability, conformability, and transferability. In 2014, the authors (Elo et al. 2014) added a fifth criterion referred to as authenticity (Elo et al. 2014).

Dependability refers to the stability of data over time and under different conditions. Conformability refers to the objectivity, that is, the potential for congruence between two or more independent people about the accuracy, relevance, or meaning of the data. Transferability refers to the potential for extrapolation. It is based on the reasoning that findings can be generalised or transferred to other settings or groups. The last criterion, Authenticity refers to the extent to which researchers, fairly and faithfully, show a range of realities (Lincoln & Guba 1985).

To address credibility, all participants were guided through the same main questions, the same introduction, and the debriefing with informants, and any additional information was taken into account during the analysis. Participants were interviewed to the point at which data saturation was achieved, the interviews were recorded on audio tape and transcriptions were made for each interview.

To allow transferability, the researcher provided sufficient detail of the context of the fieldwork for a reader to be able to decide whether the prevailing condition is similar to another situation with which he or she is familiar and whether the findings can justifiably be applied to another setting.

To achieve confirmability, the researcher paid keen attention to the data analysis so that the findings that would emerge from the data would be true and not from personal predispositions. Again, dependability is the extent to which the study could be repeated by other researchers and that the findings would be consistent. In other words, if a person wants to replicate my study, they should have enough information from my research report and also obtain similar findings as my study will do. For this reason, the data would be organised in themes and sub-themes. All interview materials, transcriptions, documents, findings, interpretations, and recommendations would be kept and made available and accessible to the supervisor and any other researcher, for the purpose of conducting an audit trail.

3.9. Data Analysis

Descriptive statistics such as means, standard deviation, frequency tables, chi-square, and one sample t-test was used at the 95% confidence interval (p-value < 0.05). In addition, the data collected through the qualitative method was analysed through the narrative method, categorising them into themes and subthemes. The data was entered into Microsoft Excel spread sheets, cleaned, coded, and transferred to SPSS to process means, percentages, and frequencies. Member checking was done to ensure that the responses gathered were without bias. The logistic regression was used to determine the underlying factors influencing the adoption of biogas technology in Ghana. Concerns and view of the participants were highlighted. The logistic regression model was used to answer the research question: What factors influence the adoption of biogas in Ghana? The logistic regression model (binary logistic regression model) used in these studies is represented as follows:

$P(Y=1|X)=1+e-(\beta 0+\beta 1X1+\beta 2X2+\ldots+\beta 9X9)1$

Where:

- $P(Y=1|X)P(Y=1|X)$ is the probability of the dependent variable (Y) being 1 given the independent variables (X).
- e is the base of the natural logarithm.
- $\beta 0$ is the intercept term.
- $\beta 1,\beta 2,\ldots,\beta 9$ are the coefficients of the independent variables $X1,X2,\ldots,X9$ respectively.

3.10. Ethical Consideration

Ethical issues form a significant element in research (Jardaneh et al. 2019). To him, a researcher needs to adhere to these ethics in order to promote the aims of the research, discover authentic knowledge and truth and prevent of errors. Therefore, the researcher maintained ethical considerations in the study by observing the following standards.

Firstly, permission and voluntary informed consents for participation was obtained from relevant institutions and individuals prior to data collection. Participation in the study was made voluntary and anonymous so that results could not be traceable to individual participants or participating schools. In the case of interviews in organisations, permission was obtained from the heads of the respective organisations to arrange a suitable time and place that could ensure visual and auditory privacy for the interviews. Arrangements were also made with all other participants for a suitable time, place or format for the interviews.

Furthermore, the researcher made it clear that the participant's names would not be used for any other purpose, nor would information be shared that reveals their identity in any way. In addition to the precautions mentioned above, it was made clear to the participants that the research was only for academic purposes and their participation was absolutely voluntary.

3.11. Challenges of Fieldwork

It is a fact that every research work comes with its peculiar challenges. The collection of data for the research was affected by two major adverse factors which posed a challenge to the researcher.

A major challenge was the withdrawal of some of the participants since they were told they could withdraw at any given time. Some of the participants declined after their affirmation to engage in the interview. They were of the excuse that they would not get the needed time to sit for about an hour to be interviewed due to their work schedules.

In addition to the above mentioned challenge, there were also other more general one. For example, the data collected was no doubt influenced by my own preconceptions, as despite all efforts at objectivity, it is difficult to completely suppress the extraordinary capacity of the human mind to see and hear only what it expects to, resolutely suppressing the noise of ordinary contradictory instances.

Thus, despite my frantic attempts to produce out with authentic reports on the perceptions and experiences of respondents, my discussions and interpretations of data cannot be completely free from the influence of my personal perceptions.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Response Rate

The response rate was 100% with 110 of the 110 sampled respondents providing their responses. For paper-based questionnaires, Bryman (2018) claimed that a response rate of above 70% is considered to be extremely good.

The findings are related to the 110 responses that were obtained, and therefore the response rate for this study was deemed very adequate.

4.2. Demographic Distribution of Respondents

Even though demographic data of respondents were not in the goals of the study, it however became expedient that such data needed to be obtained. This is because the demographic data to a large extent helped the researcher to comprehend how characteristic the participants were to the target population and the depth or richness of information they could provide. Participants were asked to provide their basic demographic information such as gender, age-range and occupation.

4.2.1. Gender of Respondents

Table 4.1: Gender of Respondents

Gender	Frequency	Percentage (%)
Male	65	59
Female	45	41
Total	**110**	**100%**

Source: Field data, 2024

From the table above, it can be seen that 65 out of the 110 respondents were male, while 45 were female. It can be seen that the male respondents outnumbered the female respondents. More males were involved in the study because there are more men in the energy sector in Ghana. These respondents provided detailed information about the study.

4.2.2. Age distribution of Respondents

Table 4.2: Age distribution of respondents

Age-range	Frequency	Percentage (%)
25-30yrs	33	30%
31-35yrs	27	25%
36-40yrs	20	18%
41+yrs	30	27%
Total	**110**	**100%**

Source: Field data, 2024

Age was significant to the study because the researcher wanted respondents who have been in the renewable energy sector for some years. It could be seen from the table above that 33 respondents representing 30% were between the ages of 25-30 years while 27 were aged between 31-35 years. Also, 20 respondents were between the ages of 36-40 years while 30 respondents representing 27% of the sample were aged 41 years and above. It can be inferred that most of the respondents were aged between 25-30 years.

4.2.3. Occupation of Respondents

Table 4.2.3: Occupation of Respondents

Occupation	Frequency	Percentage (%)
Civil Servant	20	18%
Health Personnel	16	15%
Trader	31	28%
Bank Personnel	14	13%
Others	29	26%
Total	**110**	**100%**

Source: Field data, 2024

The occupation of an individual could inform his or her perception of the adoption renewable energy particularly biogas technology.

The table above shows the occupation of respondents. Out of the 110 respondents, 20 were civil servants, 16 were health personnel, 31 were traders, 14 were bankers while 29 were into other occupations such as farming, driving and among others.

4.3 Summary statistics of Variables in the Model

Table 4.3 Summary statistics of Variables in the Model

	N	Minimum	Maximum	Mean		Std. Deviation
Biogas adoption	100	0	1	.38		.488
Cost	100	0	1	.39		.490
Environmentally friendly	100	0	1	.87		.338
Cheaper raw material	100	0	1	.81		.394
Installation space	100	0	1	.75		.435
Clean energy	100	0	1	.88		.327
Positive testimonies	100	0	1	.87		.338
Education on biogas	100	0	1	.79		.409
Reliable source of energy	100	0	1	.93		.256
Waste reduction	100	0	1	.96		.197
Valid N (listwise)	100					

As seen on the table above, it is observed that all the variables in the model has N as 100 (sample size). This is the total number of respondents who took part in the data collection (questionnaire answering). Looking at the minimum and maximum values of the variables, it is observed that all the variables have a minimum value of zero and a maximum value of one (binary variables). Looking at the mean values, it is observed that all the mean values are positive in nature, and for most of the variables, closer to the maximum value, except for biogas adoption and cost which has a mean value closer to the minimum than to the maximum value.

4.4 Accessing the general importance of biogas technology as a renewable energy source in Ghana.

In this section, the researcher intends to know the importance of biogas energy source in Ghana. This objective was attained by asking questions to know what the biogas is used for, for how long has it been in use, reasons for using it and lastly, asking to know if there are health challenges associated to the use of biogas.

Table 4.4.1 What do you domestically use biogas for?

		Frequency	Percentage%
Valid	Cooking	64	64.0
	Lighting	24	24.0
	Heating	12	12.0
	Total	100	100.0

As seen on the table above, it is observed that biogas is mostly used for cooking (64% of the respondents use biogas for cooking), followed by 24% of the respondents who reportedly use biogas for lighting and lastly, 12% of the respondent's uses it for heating. From this observation, one can confidently state that biogas is an important source of energy because respondents use it domestically and a dominant proportion of the respondents use it for cooking.

The table above can be represented on a graph, for more explicit or better transmission of information. And the pie chart below does that:

Figure 4.4.1: What do you use biogas for?

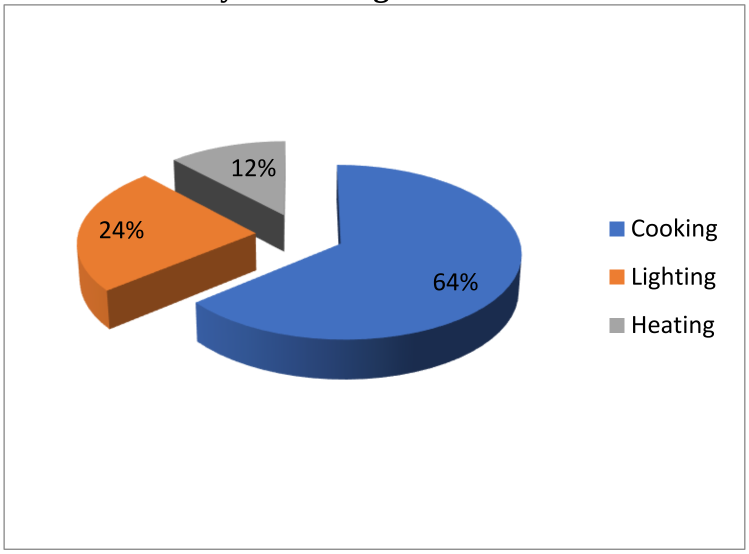


Table 4.4.2: For how long have you been using biogas?

		Frequency	Percent
Valid	Less than one year	51	51.0
	2 – 3 years	20	20.0
	4 – 5 years	16	16.0
	More than 5 years	13	13.0
	Total	100	100.0

Asking to know for how long the respondents have been making use of biogas, it is seen that a dominant proportion have been using biogas for less than a year. This proportion amounts to fifty one respondents (51% of the total respondents). Followed by those who have used the biogas energy for two to three years (making up 20% of the total respondents), and those who have used the biogas energy for four to five years (making up 16% of the total respondents), and lastly, those who have used it for more than five years (making up 13% of the total respondents).

The table above can be represented on a graph, for more explicit or better transmission of information. And the bar graph below does that:

Figure 4.4.2 For how long have you been using biogas?

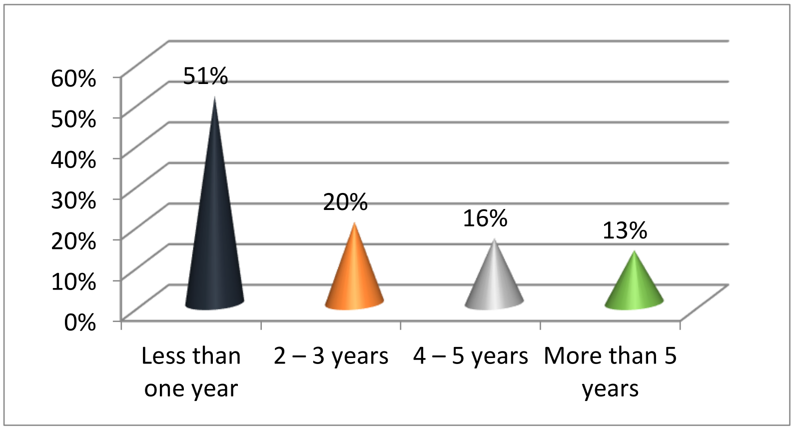


Table 4.4.3: Why do you use Biogas?

	Frequency	Percent
High cost of other energy sources	48	48.0
Influenced by friends	32	32.0
Problem finding wood fuel	11	11.0
Others	9	9.0
Total	100	100.0

Observing from the table above, it is noticed that most of the respondents choose to use the biogas source of energy because of the high cost of other sources of energy. This dominant proportion is made up of forty-eight respondents who accounts for 48% of the total respondents. The next dominant category is those who use biogas energy because they were influenced by friends and it makes up 32% of the total respondents, followed by those who uses the biogas because they face problems finding wood fuel and this set of the respondents makes up 11% of the total respondents. The least category is made up of respondents who had other reasons of using biogas. Reasons like clean source of the energy, to make use of waste, for research purposes, were stated as other reasons for using biogas accounts for 9% of the total respondents.

The table above can be represented on a graph, for more explicit or better transmission of information. And the bar graph below does that:

Figure 4.4.3 Why do you use Biogas?

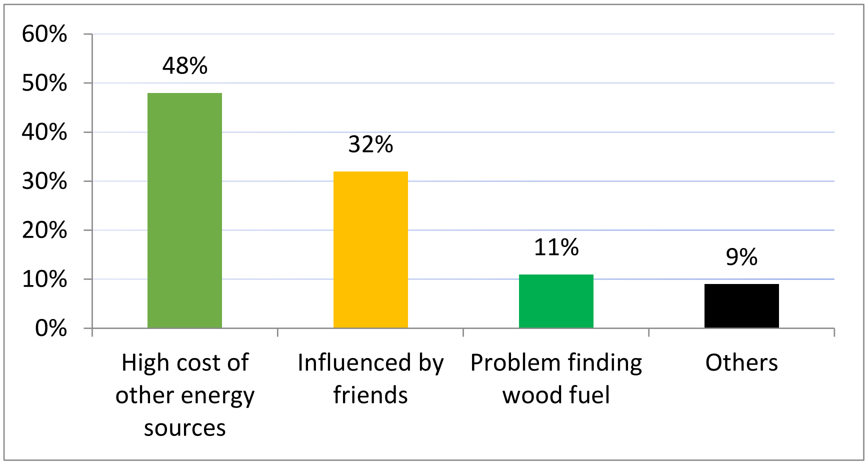


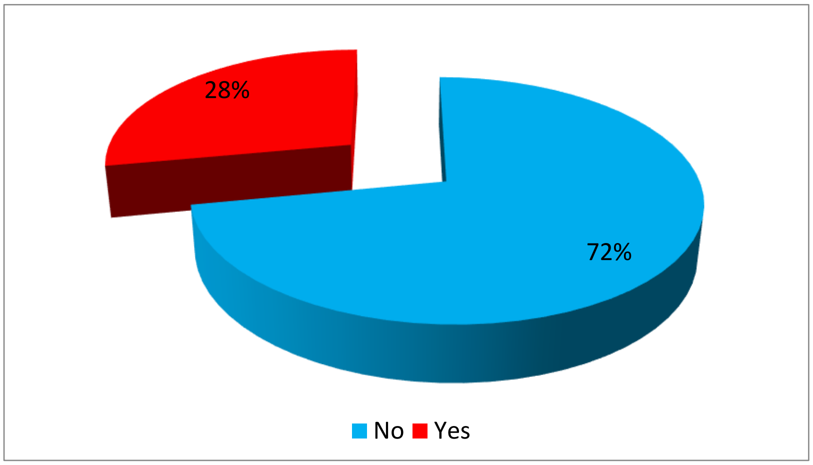
Table 4.4.4 Any health issues associated with the use of biogas?

	Frequency	Percent
No	72	72.0
Yes	28	28.0
Total	100	100.0

The table above indicates that of the respondents did not have any health issues while using biogas. This makes up 72% of the total respondents. This is followed by those whose health were affected by the use of biogas. They constitute 28% of the total respondents.

The table above can be represented on the pie chart below:

Figure 4.4.4 Any health issues associated with the use of biogas?



4.5 Determining the capacity of Ghana in the production and consumption of renewable energy

1. **Do you believe Ghana has the capacity to produce renewable energy and if 'yes' why?**

The interviewees stated that; Ghana has the capacity to produce renewable energy because of the available renewable energy sources. Water, biomass, wind, solar are all available to be used to produce energy. Ghana has the capacity to harness renewable energy given the availability of renewable sources we have in the country. There are available resources and also projects to expand the renewable energy production in Ghana. Ghana is well endowed with the available resources to produce enough renewable energy for the consumption of the country. Ghana has put in place the necessary policies and measure to ensure that the renewable energy produced is increased in the years ahead. Also there are resources available to help achieve this.

2) **Can you please tell me more about consumption of renewable energy in Ghana?**

The interviewees stated that; Ghana had an installed renewable electricity generating capacity reaching 54.28 watts per capita. This was a slight decrease from the previous year, when a capacity of approximately 54.45 watts per capita was registered. highest peak in installed capacity per capita was achieved in 2013, at 59.75 watts which gradually decreased. The installed renewable electricity generating capacity amounted to 54.28 watts per capita. This marked a marginal decline from the preceding year, which saw a capacity of around 54.45 watts per capita. The apex in installed capacity per capita occurred in 2013, reaching 59.75 watts, followed by a gradual decrease thereafter.

Also, Ghana's installed capacity for renewable electricity reached 54.28 watts per capita, marking a slight decline from the preceding year's approximate 54.45 watts per capita. Ghana produces 10.29 % renewable energy while it consumes 8.79% megawatts annually. Ghana is producing renewable energy of about 10% of total energy used whiles it consumes less of the amount of renewable energy produced.

4.6 Analysing the factors for the adoption of biogas technology as a renewable energy source in Ghana.

4.6.1 Test of global significance

The study sought to verify the significance of the logit regression model. The Chi-square value, degree of freedom and the level of significance were used.

Table 4.6.1: Test of global significance

		Chi-square	df	Sig.
Step 1	Step	17.242	9	.045
	Block	17.242	9	.045
	Model	17.242	9	.045

Source: Author's computation, (2024), *with the use of SPSS*

On the table above, it is observed that the chi-square values of the logit regression is 17.242 with a degree of freedom of nine and which is significant at a five percent level. This means that the logit regression model as a whole is significant at a five percent level.

4.6.2 Model summary (coefficient of determination)

Here, the study sought to know how much the independent variable in the model explain changes in the dependent variable. This is seen on the table below:

Table 4.6.2: model summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	115.571[a]	.158	.215

Source: Author's computation, (2024), with the use of SPSS

On the table below, it is observed that the coefficient of determination of the Cox & Snell R Square and that of Nagelkerke R Square are at 0.158 (15.8%) and 0.215 (21.5%), respectively. This means that changes in the independent variables in the model, accounts for 15.8% change in the dependent variable (according to Cox & Snell), and 21.5% (according to Nagelkerke).

Table 4.6.3 Logistic regression

	B	S.E.	Wald	df	Sig.	Exp(B)
Cost	-.373	.492	.573	1	.449	.689
Environmentally friendly	-.951	.895	1.130	1	.288	.386
Cheaper raw material	-1.078	.649	2.760	1	.097	.340
Installation space	.564	.562	1.007	1	.316	1.758
Clean energy	1.910	.884	4.674	1	.031	6.755
Positive testimonies	1.414	.811	3.038	1	.081	4.113
Education on biogas	-.337	.599	.317	1	.573	.714
Reliable source of energy	1.075	.818	1.726	1	.189	2.931

Waste reduction	-20.766	19910.061	.000	1	.999	.000
Constant	-.449	.467	.922	1	.337	.638

Source: Author's computation, (2024), with the use of SPSS

Firstly, the odd ratio of Cost, as a variable is 0.689 which is less than one (1). This means that an increase in cost decreases the likelihood of adopting biogas as a source of energy. This is expected because of the negative slope of the predictor. However, this test is not statistically significant.

Secondly, the odd ratio of environmentally friendly, as a variable is 0.386 which is less than one (1). This means that an increase in the environmentally friendly nature of biogas decreases the likelihood of adopting biogas as a source of energy. This is expected because of the negative slope of the predictor. However, this test is not statistically significant.

Thirdly, the odd ratio of cheaper raw material, as a variable is 0.340 which is less than one (1). This means that the cheaper the raw material, the more likely it is in adopting biogas as a source of energy. This is expected because of the negative slope of the predictor, and this test is statistically significant at a ten percent level of significance.

Again, accepting that biogas does not need a bigger space for its installation has an odd ratio of 1.758. This means that a lesser use of space will increase the likelihood of biogas adoption as compared to a higher use of space. However, the test is not significant.

Also, the odd ratio of clean energy is 6.755 which is greater than one (1). This means that an increase in the clean energy nature increases the likelihood of biogas adoption. This is expected because of the positive slope of the predictor. And this test is statistically significant at a five percent level of significance.

Looking at positive testimonies, the odd ratio is 4.113 which is greater than one (1). This means that an increase in positive testimonies increases the likelihood of biogas adoption. This is expected because of the positive slope of the predictor. And this test is statistically significant at a ten percent level of significance.

With regards to education on biogas, the odd ratio is 0.714 which is less than one (1). This means that an increase in education on biogas reduces the likelihood of biogas adoption. This is expected because of the negative slope of the predictor. However, this test is not statistically significant.

Looking at the reliability of the source of energy, the odd ratio is 2.931 which is greater than one (1). This means that an increase in the reliability of the source increases the likelihood of biogas adoption. This is expected because of the positive slope of the predictor. However, this test is not statistically significant.

Lastly, the odd ratio of waste reduction is 0.000 which is less than one (1). This means that an increase in waste reduction decreases the likelihood of biogas adoption. This is expected because of the negative slope of the predictor. However, this test is not statistically significant.

4.6.3 Specification test

Table 4.6.4 Multicollinearity

Variable	Collinearity Statistics	
	Tolerance	VIF
Cost	.847	1.180
Environmentally friendly	.703	1.423
Cheaper raw material	.899	1.113
Installation	.830	1.205
Clean energy	.771	1.297
Positive testimonies	.731	1.368
Education on biogas	.809	1.237
Reliable source of energy	.970	1.031

Waste reduction	.861	1.162

Source: Author's computation, (2024), with the use of SPSS

From the table above, it is observed the problem of multi-colinearity among the variables does not exist. This is because the variance inflation factor (VIF) values are all less than ten (Gujarati, 2004).

4.7 Examine the limitations of investments in renewable energy generation in Ghana.

Following interviewees, the following limitations were highlighted:

There is no support from the government for renewable energy generation. The government is not doing enough to support individuals adopting renewable energy, there is pressure to keep prices of produced renewable energy low. Most people complain of high cost of gas and electricity, there is low market size for renewable energy. Entrepreneurs are not willing to invest in this sector because of low patronage. The larger the market size, the more willing investors are likely to invest in the sector. Changing rules, regulations and interpretations of federal, state and other government entities; litigation brought by public authorities and private parties.

Also, the lack of infrastructural investment in the renewable energy sector is a major limitation. Also there unavailability of certain infrastructure has negative effects on the manufacturing and dissemination of renewable energy. Respondents revealed that changes in government and public policies affect investment in renewable energy in Ghana.

4.8. Discussion of Results

4.8.1. Importance of biogas as a renewable source of energy in Ghana

The findings presented in the thesis provides a comprehensive understanding of the adoption of biogas technology as a renewable energy source in Ghana. The study achieved a 100% response rate, which is considered extremely good according to Bryman (2018), who suggests that a response rate above 70% is excellent for paper-based questionnaires. This high response rate ensures that the findings are representative of the sampled respondents, thereby enhancing the validity of the results.

The demographic distribution of the respondents, although not initially a goal of the study, provided valuable understandings into the characteristics of the participants. The gender distribution showed a higher number of male respondents, reflecting the gender dynamics in the energy sector in Ghana. The age distribution indicated that most respondents were between 25-30 years, suggesting that the study captured the views of individuals who have been in the renewable energy sector for some years. Oduro et al. (2023) stated that a younger household or individuals are more likely to adopt biogas than older ones. This explains why the younger population adopting biogas.

The occupation of the respondents also played a significant role in shaping their perception of renewable energy, particularly biogas technology. The majority of the respondents were traders, followed by civil servants, health personnel, bank personnel, farmers and others. This diverse occupational background enriched the data collected and provided a broad perspective on the level of education of the respondents which is likely to influence the adoption of biogas. According to Oduro et al. (2023), low level of education is likely to affect the decision of a household to adopt biogas technology. This result is also similar to findings of Hafeez et al. (2017) who stated that the level of education of a household or individual is likely to influence the adoption of biogas.

According to respondents, biogas generators relieve mothers and children of the laborious process of gathering firewood. As a result, there is more time for cooking and tidying up. More significantly, cooking on a gas stove rather than an open flame keeps the family out of the kitchen’s fumes. This guards against fatal respiratory illnesses. To these respondents, one may benefit from biogas production from home thanks to home biogas systems. They are simple to install, easy to operate, and provide fertilizer and clean, renewable electricity.

4.8.2. Capacity of Ghana in the production and consumption of renewable energy

The study also examined the capacity of Ghana in the production and consumption of renewable energy. The interviewees believed that Ghana has the capacity to produce renewable energy due to the availability of renewable energy sources such as water, biomass, wind, and solar. The results confirms Agyekum et al. (2021) who stated that Ghana generates 66% of its electricity through thermal sources with hydropower making up the remaining 33%. According to Aboagye et al. (2021) also reiterated, stating that solar, geothermal, wind, oceanic, nuclear, biomass and biofuels are examples of renewable energy sources that can be utilised again to produce energy and play a vital role in supporting the nation's future economy and environment.

According to Agyekum et al. (2021) power sector reforms in the 1980s gradually dismantled obstacles and levelled the playing field for independent power producers' participation in a field that had previously been dominated by players from the public sector. The main sources of Ghana’s power supply are still hydroelectric generating and thermal generation powered by fuels including natural gas, diesel, and crude oil. Ghana also sells electricity to Burkina Faso, Benin, and Togo.

4.8.3. Factors that influence the adoption of biogas technology as a renewable energy source in Ghana

The third objective of the study was to analyse the factors for the adoption of biogas technology as a renewable energy source in Ghana. The results from the analyses revealed interesting findings on the variables used. All the variables had a minimum value of zero and a maximum value of one, indicating that they were binary variables. The mean values were positive, with most of them closer to the maximum value, except for biogas adoption and cost, which had mean values closer to the minimum.

The logistic regression analysis provided insights into the factors influencing the adoption of biogas technology. Variables such as clean energy and positive testimonies had a positive impact on the likelihood of biogas adoption and were statistically significant. However, variables like cost and environmentally friendly nature of biogas had a negative impact on the likelihood of biogas adoption, although they were not statistically significant. Although there not article related to this specific variables, the results indicated that clean energy and positive testimonies or recommendations from people greatly influence the choice of biogas.

The cost of biogas has been the main factor influencing the adoption of biogas technology in the Central Region of Ghana, confirms a study undertaken by Scarlat, Dallemand and Fahl (2018) in Spain. Scarlat et al. (2018) found out that consumers weigh a variety of factors before accepting or rejecting an invention, and one of the most important is the cost of the technology.

To hasten the adoption of these technologies, governments and NGOS should take the initiative to offer external support through subsidies. Food and Agricultural Organization (FAO 2019) stated that it would be unfair to require individual users to cover the whole cost of a technology whose advantages are also enjoyed by non-users.

Concerning the environmental friendliness of biogas Lybaek and Kjaer (2022) emphasized that methane emissions from landfills and manure lagoons are reduced with the use of biogas. By turning this methane into CO_2, which has a climate impact that is up to 34 times less severe than CO, using it as fuel has a significant positive impact.

4.8.4. Limitations of investments in renewable energy generation in Ghana

The last objective of the study was to examine the limitations of investments in renewable energy generation in Ghana. Despite the respondents belief in the country being able to produce renewable energy, however, they highlighted several limitations to investments in renewable energy generation in Ghana, including lack of government support, high cost of gas and electricity, low market size for renewable energy, and changing rules and regulations.

CHAPTER FIVE

CONCLUSIONS

Energy is regarded as the most important aspect in socioeconomic development and has a direct impact on a nation's overall progress. Government plans for economic growth and meeting rising energy demands are common in emerging nations, but there is also a desire to increase energy supply and security and lessen the negative environmental (especially climate) effects of fossil fuel-based energy production.

In this study, factors influencing the adoption of biogas technology as a renewable source of energy in Ghana are examined, focussing on the Central Region. The need to reduce waste, secure other sources of renewable energy and avoid the rapid depletion of the ozone layer hinted at the introduction of biogas technology. Anaerobic digestion of energy crops, residues, and waste is of increasing interest in reducing greenhouse gas emissions and facilitating the sustainable development of the energy supply (Weiland 2009). The production of biogas provides a versatile carrier of renewable energy. For example, methane can be used to replace fossil fuels in both heat and power generation and as a vehicle fuel (Xinshan et al. 2005). The use of bio digester plants is also not commonplace in Ghana. Few institutions and individuals have adopted this technology and are mainly concentrated in urban areas. In 1997, the Energy Commission (EC) was founded, among other functions, to develop, regulate, and manage renewable energy resources in Ghana. In 2006, the EC developed the Strategic National Energy Plant (SNEP) a policy document that defined the role of various energy sources, setting targets for each within twenty years. From SNEP, biomass-based energy, in addition to its direct use as wood fuel (firewood and charcoal), has been exploited to a very limited extent in Ghana. Wood fuel represents the traditional energy source in Ghana and represents 60% of the total energy used. (Cudjoe Bensah & Brew-Hammond 2010). As of 2015, the total capacity of renewable energy power installations amounted to 9.95 MW consisting of 7.99 MW from Solar PV and 1.96 MW from biomass-fired.

Although there are some policy efforts towards expanding renewable power generation, the lack of adequate, coherent and consistent policies; technical skills; institutional capacity; and infrastructure prevents the country from benefiting from the enormous environmental, social and economic opportunities that the country stands to benefit from. Further opportunities for value creation exist from improvement in energy efficiency in the country. To fully take advantage of the environmental and socio-economic benefits of renewable energy and energy efficiency improvements, there is the need for the right mix of cross-sectoral (residential, commercial and industrial and utility-level) policies. A policy decision to lower the financial burden associated with acquiring rooftop solar systems for homes, offices and commercial/industrial customers and also to lower the cost of grid integration would be necessary to encourage presume ownership of renewable energy systems.

The study underscores the fact that outstanding reconsideration and firm commitment at all levels (government and non-government organisations, energy experts, private enterprises, research institutes, farmers) to improve a household' decision to adopt biogas technology and enjoy the multiple benefits of the technology would go a long way to enable households in Ghana to adopt biogas as a renewable source of energy, thus reducing dependence on fossil fuels and other forms of non-renewable energy.

5.1. Recommendations

In the light of the findings of this study, the following recommendations are put forward for policy implementation.

First, it is recommended that to overcome the multifaceted obstacles of biogas technology adoption, it is necessary to re-consider and hold firm at all levels (government and non-government organisations, energy experts, private enterprises, research institutes, farmers) to improve the decision of a household to adopt biogas technology and enjoy the multiple benefits of the technology. Stakeholder institutions should arrange smooth and reasonable credit sizes for all potential adopters to improve households' decisions to adopt biogas technology.

Second, the study recommends that the United Nations, in collaboration with the African Union, make the use of renewable energy a global public good. It will be crucial to reduce barriers to knowledge sharing and technological transfer, especially those relating to intellectual property rights, in order for renewable energy technology to be a global public good, meaning accessible to everyone and not just the wealthy. Energy from renewable sources, such as solar and wind, can be stored and released when people, communities, and businesses need power due to crucial technologies such as battery storage systems. According to the International Renewable Energy Agency, they contribute to greater energy system flexibility because of their exceptional ability to instantly absorb, store, and re-inject electricity.

Moreover, the government of Ghana should invest heavily in renewable energy. The researcher believes that to achieve net-zero emissions by 2050, we must invest at least $4 trillion annually in renewable energy until 2030. This amount includes expenditures in infrastructure and technologies. This investment will pay off, though it will not be quite as high as annual subsidies for fossil fuels. By 2030, reducing pollution and its effects on the climate could generate annual savings of up to $4.2 trillion.

In addition, the Ghana Energy Commission should promote a level playing ground for innovations utilising renewable energy. Urgent changes must be made to domestic policy frameworks to streamline and accelerate renewable energy projects and encourage private sector involvement.

It is also recommended that Ghana's government introduces financial incentives such as soft loans and subsidies at the initial stage. The government should also provide support to local energy Non-governmental organizations (NGOs) as KITE and Centre for Energy Environment and Sustainable Development (CEESD) who will then provide periodic technical and financial support to domestic biogas owners.

Finally, the government of Ghana through the Ministry of Energy and Communication should embark on intensive public education on the use of biogas technology. This should be done to inform people that biogas technology exists and that it can contribute to improving community livelihood, environment, and economy, thus alleviating poverty.

5.2. Suggestion for further studies

Based on the findings and conclusion on the study, the following suggestions are hereby put forward for further studies.

The study only covered only the Central Region of Ghana. The researcher therefore suggests that there should be a replication of the study in other districts and regions outside the Central

Region in order to ascertain the validity of a study of this kind and make the findings more generalised.

Impact of biogas use on indoor air quality and health benefits to users considering the time before and after adoption

Further research is needed on the amount of tree cover that can be saved by biogas use locally.

The fact that electricity demand has been forecasted empirically, little empirical studies is known on the intensity of energy consumption in the country, energy conservation and willingness to pay for better energy services. Thus, for policy purposes, other areas like intensity of energy use, conservation behaviour, and willingness to pay for energy services need to be researched into.

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APPENDIX

APPENDIX 1. Survey questionnaire

QUESTIONNAIRE

Introduction

I am Thaddeus Tawiah Bilson, a student of Czech University of Life Sciences Prague. I am currently conducting a study leading to the award of Master of Science degree in TFS, Sustainable Technologies. The purpose of the study is to determine factors that influence the adoption of biogas technology as a renewable energy source in central region, Ghana. I humbly ask for a sacrifice of your time to partake in the administration of questionnaires which will last for barley less than an hour. Your co-operation is therefore highly needed to empower the success of the study.

All responses will be kept confidential. This means that your responses will only be shared with research team members, specifically, my supervisor and the Department of Sustainable Technologies. We will also make sure that any information we include in our report does not identify you as a respondent. Please note that you are not obliged to talk about anything you do not want to and as such, you may withdraw from this exercise at your own will. Thank you for the acceptance to participate in the study.

Yours Sincerely,

Thaddeus Tawiah Bilson

Part 1: Demographic Data

(Instruction: Please tick where appropriate)

1. What is your Gender?

   (a) Male [ ]

   (b) Female [ ]

2. Age range

   (a) 25-30yrs [ ] (b) 31-35yrs [ ]

(c) 36-40 yrs [ ]   (d) 41+yrs   [ ]

3. What is your occupation?

(a) Civil Servant [ ]   (b) Health person [ ]

(c) Trader [ ]   (d) Bank personnel

(e) Other, pls specify…………………..

Part 2: Importance of biogas technology

4 Do you use biogas?

(a) Yes [ ]   (b) No [ ]

5. What do you use your biogas for?

(a) Cooking [ ]   (b) Lighting [ ]

(c) Heating [ ]

(d) others (specify)……………………..

6. Who introduced you to the use of biogas?

(a) Wife [ ] (b) Husband [ ]

(b) Children [ ] (d) Friends [ ] (e) other relatives [ ]

7. Since when have you been using biogas as a renewable source of energy?

(a) 2-3 years [ ]   (b) 4-5 years [ ]

(b) (c) 6-7 years   (d) more than 7 years [ ]

8. What do you use for the production of your biogas?

(a) Animal manure [ ]   (b) Municipal waste [ ]

(c) Plant materials [ ]   (d) Food or sewage waste [ ]

(e) Others, please specify…..

9. Why did you adopt biogas technology?

(a) Acute problem of fuel wood for domestic use [ ]

(b) High costs of other energy sources [ ]

(c) Influenced by friends who have already adopted [ ]

(d) others(specify)…………….

10. Is biogas technology sufficient to meet your energy needs?

(a) Yes [ ] (b) No [ ]

11. Have any of the household members ever faced any health problems associated with the use of fuel?

(a) Yes [ ] (b) No [ ]

12. If yes, for Q. 11, which health problem(s) has (have) faced your household member(s)?

(a) Eye diseases due to smokes [ ] (b) Coughing [ ]

(c) Difficulty of breathing [ ] (d) Burning accidents

(e) Injury/violence during collection [ ] (d) others, specify……………..

Part 3: Factors for the adoption of biogas technology in Ghana

The following statements relate to factors that influence the adoption of biogas technology in Ghana. Please tick the response that best suits you considering your experience with the use of biogas so far.

13. Biogas technology is expensive as compared to other sources of energy.

(a) Yes [ ] (b) No [ ]

14. Biogas is environmentally friendly

(a) Yes [ ] (b) No [ ]

15. Raw materials for biogas production is cheaper and easy to obtain

(a) Yes [ ] (b) No [ ]

16. Installation of biogas plant do not require a lot of space

(a) Yes [ ] (b) No [ ]

17. Biogas fuel produces clean energy which do not compromise human health

(a) Yes [ ] (b) No [ ]

18. I adopted biogas because of the positive testimonies of people concerning its use

(a) Yes [ ] (b) No [ ]

19. I adopted biogas due to the education I receive concerning biogas technology

(a) Yes [ ] (b) No [ ]

20. Biogas is a reliable source of energy

(a) Yes [ ] (b) No [ ]

21. Biogas technology reduces the volume of waste due to human activities

(a) Yes [ ] (b) No [ ]

APPENDIX 2. Interview questions

INTERVIEW-GUIDE

What factors influence the adoption of biogas technology as a renewable energy source in Ghana.

1. Can you please tell me about your role /work in this organization?

2. How are you involved in biogas technology as a renewable source of energy in Ghana?

3. What can you say about the importance of biogas technology as a renewable source of energy in Ghana?

4. Do you believe Ghana has the capacity to produce renewable energy and if 'yes' why?

5. Can you please tell me more about consumption of renewable energy in Ghana?

6. From the perspective of your company, what do you think is the motivation for the adoption of biogas technology in Ghana?

7. How does the Ghana government encourage investors to invest in the renewable energy sector?

8. Do you think there are limitations of investments in renewable energy generation in Ghana?

9. If ‘yes’ or ‘no’ can you please explain?

10. In your own view, how can these limitations be addressed effectively?

11. Is there anything else you think I should know about your experiences in the renewable energy sector?

APPENDIX 3: data collection pictures

Images from some biogas digestors installed by Green Gas Technology for an individual.