CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical Agrisciences

Biogas in Developing Countries and the SDGs: A Comparative Cross-Fuel Analysis for Biogas and Other Cooking Sources in Central Region of Ghana; Case of Awutu Senya East and Effuttu Districts

MASTER'S THESIS

Prague, 2023

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Declaration

I hereby certify that I worked independently on the thesis titled "Biogas in Developing Countries and the SDGs: A Comparative Cross-Fuel Analysis for Biogas and Other Cooking Sources in Central Region of Ghana; Case of Awutu Senya East and Effuttu Districts," that all texts in this thesis are original, and that all other sources have been cited and acknowledged through complete reference and following the FTA's citation guidelines.

In Prague 15/05/2023

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AGGREY-SEY FIIFI

Acknowledgment

Without the formidable assistance of Assoc. Prof. Ing Hynek Roubik, Ph.D., this work would not have been possible. His patience and guidance were instrumental in the success of this project. I'd like to thank everyone I've had the pleasure of working with during this time. My thesis group members (Ebbo Aggrey-Sey, Kwadwo Dei, Constance Manu, Adwoa Aframa, Baaba Payne, Araba Gyasiwa, Oluwatobi Aramu, and Oliver Tulasi, Lilian Jakubcova) provided me with extensive personal and professional guidance, as well as a wealth of knowledge about scientific research and life in general. I'd like to express my gratitude to Emmanuel Duah in particular. He taught me more than I could teach him here. He demonstrated to me what a good person and scientist should be by his example. Nobody was more important to me in the project search than my family members. I'd like to thank my parents, whose love and guidance have been with me in everything I've done. They are the last line of defence. I'd like to express my gratitude to my supportive and loving wife. Constance Aggrey-Sey and my kids Taraji Esi Aggrey-Sey and Kimathi Aggrey-Sey

Abstract

The study's goal was to determine the potential use of biogas as an alternative to solid fuels and LPG (liquefied petroleum gas) currently used in rural and peri-urban households, as well as the benefits and limitations of introducing household biogas technology in Ghana, using two communities as study areas (Effuttu and Awutu Senya East). Using a hybrid technique of data collecting, 304 responses from household heads were compiled in total. (Qualitative and quantitative). Environmental officers from the two municipalities were also questioned as part of the study. Using SPSS version 20 and also Microsoft excel, an analysis of the field data and the presentation of descriptive statistics and frequencies were done.

Of all the respondents questioned during the study ,65 families, or 4% of those who responded to the survey, have adopted, and use biogas technology. Overall, 92.3 percent of the factories were built with personal funds from families, with NGOs funding 7.7 percent. Biogas generates clean energy and is simple to use and maintain, according to most homeowners. Respondents believe that using biogas increases energy supply and decreases time spent collecting firewood and cooking, giving women and children more time to participate economically in education and other businesses.

According to the findings of the study, the Ghanaian government has made very little effort to promote the use of biogas technology by failing to develop policies that promote and encourage the use of renewable energy sources such as biogas. Furthermore, some non-governmental organizations (NGOs) that primarily focus on women's empowerment and rural development have made some efforts to provide education and financial support for biogas projects, but their efforts and approaches have yielded very little due to the numerous challenges they face, most notably a lack of financial resources. The way forward, which is primarily in the hands of the Ghanaian government, is to prioritize biogas adoption through effective policies that provide a solid platform for implementation for NGOs and private companies. This can be accomplished using economic tools such as tax breaks and subsidies, as well as increased education about the benefits of biogas technology adoption and use, as well as the negative impacts of alternative energy sources. current.

Key words: Biogas, Energy consumption, Fuel sources, Households, Feedstock, Digestate

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List of Abbreviations

ANOVA…………………………………………………………………………Analysis of variance

AIDS……………………………………………………...acquired immunodeficiency syndrome.

EC……………………………………………………………………………. Energy Commission

GDP………………………………………………………………………. Gross domestic product

UN……………………………………………………………………………………. United Nations

HIV………………………………………………………………Human Immunodeficiency Virus

IPCC…………………………………………………Intergovernmental Panel on Climate Change

LEAP……………………………………………Long-range Energy Alternative Planning System

LPG………………………………………………………………………Liquefied Petroleum Gas

MANOVA………………………………………………………. Multivariate analysis of variance

NGO……………………………………………….………………Non-Governmental Organisations

SSA……………………………………………………….…………………. Sub-Saharan Africa

SDGs…………………………………………………………………...Sustainable Development Goals

UNICEF………………………………………………………. United Nations Children Fund

1. 0 INTRODUCTION

1.1 Background of the Study

For the average African, when it comes to biogas, faces a very different set of conditions in which to follow the use of different fuels. In the city, it is difficult to think of the use of biogas as a fuel. People in most African cities are familiar with the term "biogas," but it is rarely mentioned in rural areas in Ghana. The popularity of biogas in developing countries has been exaggerated in the literature. In the developed countries, biogas is a common fuel source, but it has been neglected until recently due to its significance in environmental conservation by transforming waste into useable fuel. When compared to widely available and affordable petroleum-derived fuels in affluent countries, biogas was a too lean and inconvenient fuel (Abassi et al., 2012).

There has been a lot of debate as to whether biogas can become the new fuel for most of the world's countries. Biogas became known as the sustainable energy in the 1970s when crude oil shocks compelled countries to heed its warnings. but once normalcy was restored, it reverted to its previous state. Growing awareness of the effects of gases such as carbon dioxide and methane (methane is a potent greenhouse gas, producing approximately 25 times more GW than a molecule of CO2 (IPCC 2007)) has drawn the attention of the United Nations (UN), among others, to introduce Sustainable Development Goals. According to the data, the United Nations has done an excellent job of eliminating 98 percent of ozone-depleting substances since 1990.

Furthermore, in 2015, 91 percent of the world's population drank water from a better source, and 2.1 billion people now have access to improved sanitation (Dada, 2018). To meet the Sustainable Development Goals, nations and organizations have taken action to safeguard the environment by extracting methane and utilising gas for these and other uses. Some wealthy nations have surpassed emerging ones, like as China, which began utilizing biogas millennia ago. To fulfil their fuel and sewage demands while battling climate change. Many African nations, particularly those in sub-Saharan Africa, will rely heavily on the usage of biogas.

1.2 Problem Statement

When countries like Ghana struggle to strike a balance between population growth and infrastructure issues, they occasionally deal with serious implications. These situations can result in poor sanitation and high levels of forest loss due to the high demand for affordable cooking fuel and water supplies. Energy from waste has been a top concern in recent years for many developing nations, notably in Africa, because of bad sanitation and an energy crisis. Technology for producing high-quality renewable fuels from biogas has developed to the point that it is now commonly employed Biogas technology has advanced to the point where it is now widely used to produce high-quality renewable fuels. The country's ability to use biogas as a required replacement for other fuel sources, as well as how biogas preserves the environment and advances the Sustainable Development Goals, must be evaluated.

Development Goals.

1.3 Aim and Objectives of the Study

a) The research aims to:

- Consider the pros and cons of introducing indigenous biogas technology in Ghana and its potential to replace solid fuels and LPG (LPG) in rural and peri-urban households.

b) The objectives are:

- Analyze household opinions and knowledge of using biogas versus wood fuel.
- Find out how the use of biogas technology in the home has an impact on the socio-economy, health, environment, and climate compared to the use of

firewood.

- Determine the primary obstacles to the use of biogas technology.
- Determine the amount of organic waste that can be used to produce affordable, reliable, sustainable, and modern energy.
- Describe the measures taken by the Ghanaian government to promote the use of clean renewable energy in response to the Sustainable Development Goals.

1.4 Research Questions

The developed research objectives lead to the following main research questions:

- What is homeowners' perception on adopting and using biogas?
- Are there any socio-economic, environmental, health and climate benefits in adopting and using biogas?
- What obstacles hinder the adoption of biogas in the study area apart from the lack of knowledge on it.
- How much organic waste can be used to produce energy in a cost-effective, reliable, green, and modern way?
- Who are the main players in waste biogas production in Ghana?

1.5 Justification of the Study

Despite severe energy shortages, Ghana has access to renewable energy sources, including solar, biomass and hydropower. Renewable energy can help increase energy availability and overcome energy challenges if effort and attention is focused on it. In Ghana, non-renewable energy sources are prioritized, and less attention is paid to renewable energy sources. This research is significant since it helps to determine Ghana's biogas potential. This study will assist in identifying the obstacles to biogas use in Ghanaian organizations, families, and enterprises and will offer suggestions for ways to overcome these obstacles. In addition, this study will assist close any gaps in the current biogas literature because this research field has not yet been thoroughly investigated in Ghana. The many institutions and organizations involved in waste management as a business should also take note of the significance of this study.

1.6 Scope of the Study

The research will primarily take place in Ghana's central region. Due to the length of the study, the focus was on the Kasoa and Winneba communities. However, data relevant to determining community biogas potential will be collected from companies that provide these services to communities but do not live in the community. Information was also gathered about these communities' governments and private offices as well. The focus is on households and businesses that use or do not use biogas.

1.7 Conceptual Framework for the study

A conceptual framework for explaining the continuous reliance on and usage of wood fuels is provided in Figure 1. Forests deteriorate as a result, and biomass decreases. Due to severe scarcity and increasing demand, firewood prices are rising. Furthermore, women and children are more vulnerable because of the effort required to collect and cook with firewood. This has the potential to harm human well-being.

Additionally, by converting to biogas, homes may obtain better energy services that enhance human well-being by lowering fuel expenses and cooking energy use, enabling a more sustainable use of natural resources. The availability of fuel biogas eases strain on the forest. Additionally, since the installation of biogas plants and the use of biogas stoves lower indoor smoke levels it enhances the health of people, families, and communities. Because biogas saves women and girls from long journeys to find firewood, time spent preparing fires, and constant fire tending, the presence and use of biogas by families will save time and reduce workload. Time spent collecting firewood could be spent more productively on farming, childcare, business ventures, craft projects, and community services.

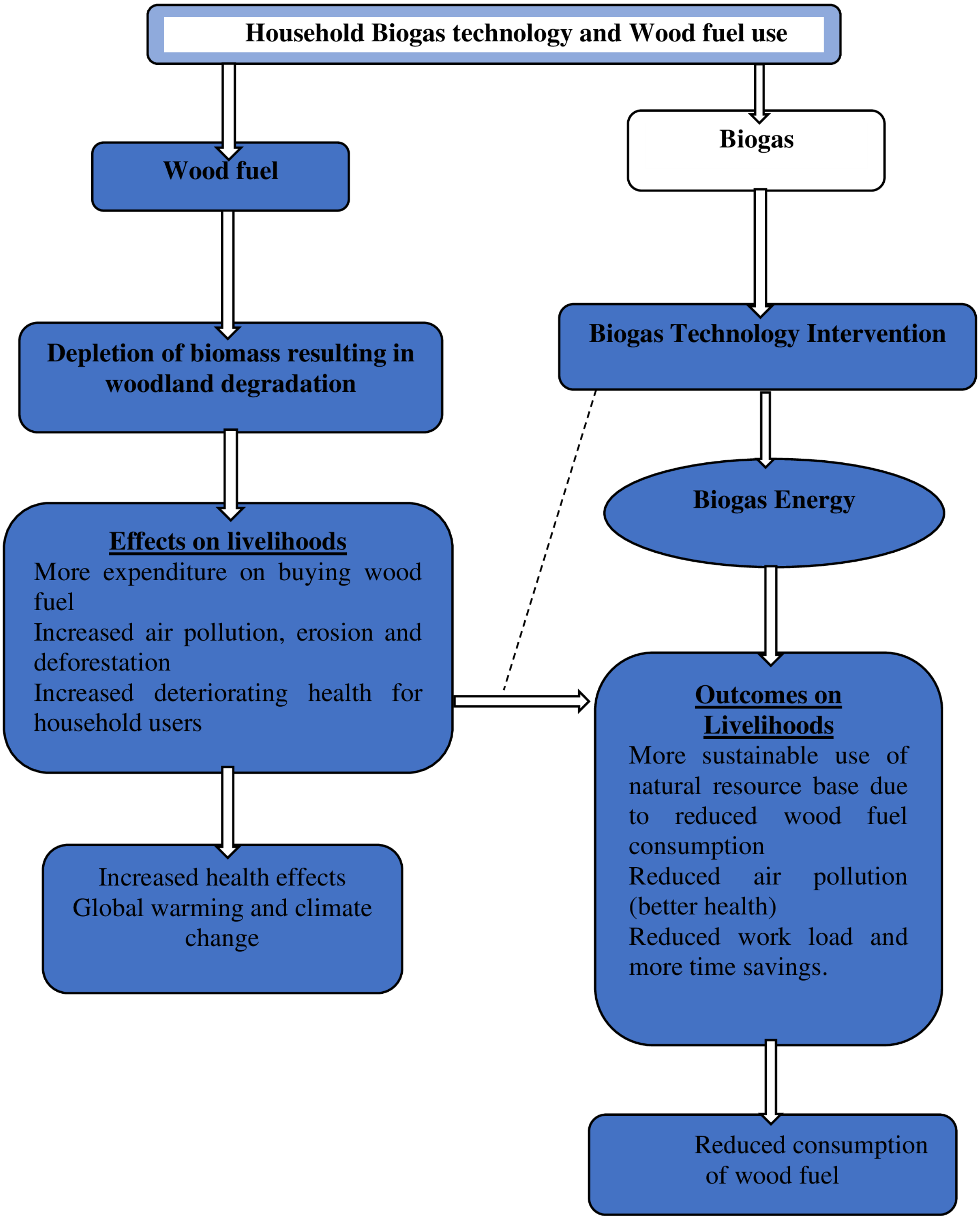

Figure 1: Conceptual Framework for Household Technology & Wood Fuel Use.

2.0 LITERATURE REVIEW

2.1 Energy Crisis in Africa

In addition to the expected threat of a warming climate, recent energy problems and fossil fuel depletion have become a worldwide concern over how they will affect future generations sparking widespread interest in the development of environmentally friendly, renewable, and zero-emission alternative fuels to meet rising energy demand (Pathak, 2014). Because of the scarcity of conventional fossil fuels, their exploding prices, and the increase in greenhouse gas emissions, this overview of the energy crisis clearly shows that biomass sources have proven to be more efficient. Many of the world's remaining oil reserves are concentrated in the Middle East, where they are rapidly depleting. (Okogu, 2003). These methods of assessment included how to deal with the energy crisis and how to protect the environment while the solutions followed sustainability and environmental protection. As people become more aware of resource depletion and climate issues, there is a great opportunity to reduce greenhouse gas emissions from livestock by utilizing the energy content and nutritional value of manure. (Food & Bio Cluster, Denmark, 2020).

The state of Africa's energy crisis is inextricably linked to the continent's developments (Achor, 2012). The continent's underdevelopment is undeniably due to the continent's energy crisis. Achor (2012) investigated the African energy crisis in depth, using Nigeria as a case study because of its population. The findings show, among other things, that even highly educated people are only partially aware of Nigeria's energy crisis. Most people are unaware of how poorly maintained society and a waste culture contributed to the crisis. Corruption, conscientious objection, and illiteracy, on the other hand, were major contributors to energy shortages (Achor, 2012).

Most Sub-Saharan African (SSA) households continue to lack access to modern forms of energy, with only about 30% of the population having access to electricity and 90% relying on traditional fuels for cooking and heating (Brew-Hammond, & Kemausuor, 2009). Commercial, industrial, and residential structures in Ghana use both fossil fuels and renewable energy sources. Some of these fuels are produced abroad and imported. Ghana's energy supply consists mainly of three components: biomass energy in the form of fuel and coal; hydropower generated by the Volta River Authority from the Akosombo dam; and commercially available fossil fuels, especially petroleum products. In addition, renewable energies such as wind and solar power are used in the country.

2.2 Biogas as a renewable source of energy

Biogas is a renewable, environmentally friendly, and economically viable energy source becoming a life blood to humanity according to as s per Geddafa et al. (2002). In fact, it has not only helped solve the global energy crisis, but it has also helped manage critical resources and waste that pollutes and kills our planet. As time progressed, engineers, scientists, and organizations have attempted to improve the use of biogas for many purposes. An enumerated of these includes efforts to ensure cleaner environment through biogas' ability to remove problematic substances from the environment and slowing the growth of pollutants like methane. Both biogas and biomethane can be produced and used in a variety of ways. (International Energy Agency (ESIO),2020).

The anaerobic environment transforms the biological material into biogas. Cattle manure, poultry manure, pig offal, kitchen waste, grass mold and algae are all raw materials for biogas production. Biogas has proven to be an effective alternative to wood fuel and manure as a cooking and heating fuel in countries where agriculture is an important part of the economy. (Arthur et al., 2011a). Governments should consider other sustainable and cost-effective alternatives to unsustainable wood fuels due to the significant health risks and environmental impact. (Arthur et al., 2011a). Biogas is an energy source that has been used since the 10th century BC by the Assyrians to heat bath water. (Bond, & Templeton, 2011).

The Chinese, legend has it, used bamboo pipes to transport biogas for lighting. (Harris, 2014). Van Helmont is credited with discovering combustible gases from rotting vegetables in the 1630s. The first biogas plant in India was built in Bombay. (Meynell, 1976). This application of biogas has spread to Europe and has led to intense research into the advancement of microbiology as a discipline. Two prominent authors who conducted research in this field.

were G.E. Simmons and A.M. Buswell studied anaerobic bacteria and how they help produce methane. It would be impossible to list and assess all the biogas literature. However, some key aspects are discussed here to demonstrate progress and highlight gaps that need to be filled. Deublein Dieter and Angelica Steinhauser have written a remarkable history of biogas from the Sumerian civilization to the present in their book Biogas from Waste and Renewable Resources: An Introduction. (Deublein, & Steinhauser, 2010). This book reviews recent advances in biomass technology. The origins of the author influenced the quality of the material.

The book also discussed the current state and future of the European biogas industry, but very little about biogas in developing countries is mentioned. (Deublein & Steinhauser, 2010). India and China are leading the way in producing biogas from animal waste to provide essential energy to rural farmers in developing countries. In essence, they saw biogas as a viable fuel amid the "oil shock" crisis that struck developed countries in 1973–1979. In the 1980s, when the crisis subsided and the price of oil fell, biogas and other non-conventional energy sources in rich countries disappeared from grace. (Abbasi et al., 2012).

Biogas Energy is a book providing detailed introduction to biogas, revealing the history of biogas and the various types of biogases, as well as discussing biogas and global warming. This paper is of high quality and conveys in simple terms a key component of biogas energy. The increasing popularity and demand for biogas has triggered interest in modernization research. The upgrade of biogas is widely researched and discussed, and its use as natural gas replacement has attracted a lot of attention in recent years. There are numerous applications for biomethane production, including heat and power generation, as well as vehicle fuel. This document provides an in-depth look at biogas upgrading technologies, including increasing efficiency, reducing methane (CH4) losses, minimizing environmental impact, development and commercialization, energy consumption management, and economic evaluation challenges. (Ullah Khan et al., 2017).

2. 3 Energy Demand in Africa

Every time the clock ticks, energy is utilised. Energy is life, so the uses are endless. The continent of Africa is rich in energy resources but in desperate need of energy. Biomass energy accounts for more than 30% of energy consumption on the continent and more than 80% in many sub-Saharan countries. (Kebede et al., 2010). Of all the continents on Earth, Africa has the largest energy needs. Africans utilize significantly less energy than Englishmen did a century ago on average. (Beg et al., 2002) and (Wolde-Rufael, 2005). As the continent's population grows, energy demand remains a problem. Moreover, in a rapidly changing world, Africans tend to be reluctant to diversify their energy sources. Researchers have looked at Africa's energy needs from different angle. Kebede et al. (2010) used cross-sectional time series data from 20 nations to analyse and generalize the overall energy consumption in the central, eastern, southern, and western regions of sub-Saharan Africa over a 25-year period.

The study assessed the energy needs of these areas and concluded that there are regional differences in energy needs and that Africa can only meet its needs by diversifying its energy sources. The report's authors say demand for electricity has exceeded that of any other energy source, and they believe that by meeting this demand and using technology, poverty can be reduced. (Kebede et al., 2010). Energy needs analysis is a crucial part of integrated energy planning and policy in emerging countries. Planners and policy makers need to fully understand the variables that influence growth and energy demand patterns before they can estimate future demand (Ramesh Bhatia, 2013). Ramesh provided a general summary of how to study energy demand in developing countries. His research on energy consumption in various sectors in this context has focused on Asian countries.

The way he perceived the energy in his art was influenced by his encounters with it in India. However, he has provided researchers with a solid platform for exploring the energy needs of global developing countries. It stressed the need for further research on energy consumption analysis and made recommendations to this effect in emerging countries such as Africa. Since it is easy to identify Africa's energy demand by looking at it, most academics rarely examine the continent's energy consumption, instead mentioning it only in their articles. Due to Africa's ever-increasing energy needs, insufficient resources, heavy reliance on fossil fuels to meet those needs, and global concerns about environmental problems caused by energy, the long-term forecast of supply and demand is essential. (Ouedraogo, 2017). In this study, current and future demand was analysed based on socio-economic factors such as population and urbanization.

The analysis and forecasting of the African energy demand was done using the Long-Range Alternative Energy Planning System (LEAP) Modelling framework. He noted that access to contemporary energy services is still restricted, even though energy supplies are more than sufficient to meet household needs. Two-thirds of Africans, or more than 620 million people, lack access to electricity, while almost 730 million cook using conventional solid biomass. The literature that is now accessible on African energy demand is peculiar, and most publications hardly ever address this topic. They only talk about issues that are local and global. But because of all this study, experts think that energy, especially electric power, will be crucial to Africa's development.

2.4 Energy Demand in Ghana

The government has invested a lot of effort and money to provide Ghana with the electricity it needs. The expression "Dum Sor", which translates to "turn on and off", arose from the need for electricity. Electricity supply in Ghana is unreliable. Ghana has a high energy demand. Consequently, the production of biogas using Waste to Renewable Energy (WTRE) technology is considered one of the best solutions to meet the growing energy needs around the world. Hynek Roubik and Jana Mazancová in 2020. Until recently, Ghana paid little attention to energy studies. Meanwhile, Ghana has suffered at least five major energy crises since 1984. These crises have been linked to various causes, including climate change trends, invasion of the Sahara, complacency with politics and even the persistent postponement of tough energy decisions when national security is threatened. (Kwakwa, 2012a).

Both the micro level and the aggregate level of Ghana's energy demand were analysed to provide a deeper understanding of the country's energy consumption (Kwakwa, 2012a). The research collectively aimed to identify the root of the increased demand for electricity. Using the ARDL Bounds cointegration method and the sampling period from 1975 to 2005, Bekoe and Adom (2012) evaluated the influence of the components responsible for historical growth trends on total national energy consumption.

Real GDP per capita, industrial efficiency, economic structural changes and degree of urbanization have been identified as the main drivers behind the historical trend of growth in total domestic demand for electricity. In the short term, however, industrial efficiency, degree of urbanization and real GDP per capita are the most important determinants of total domestic energy demand. Scientists have focused more on the micro level, where energy consumption consists of electricity, firewood, kerosene, and LPG. (Kwakwa, 2012b). At the micro level, there is more demand for energy than at the macro level. According to Kwakwa et al. (2013), the dependence and use of firewood (wood and coal) does not produce positive results, so the government plans to subsidize liquefied petroleum gas (LPG) for domestic use with the dual purpose to reduce poverty.

Most Ghanaians continue to use firewood despite these safety measures. 507 family heads from the nation's savannah and forest regions were consequently picked for the study. Many respondents indicated that 74.2 percent of households use electricity, 72.6 percent use coal, 57 percent use firewood, 32.5 percent use kerosene, and 36.1% use LPG. (Kwakwa et al., 2013). Consequently, they concluded that the only way to meet this requirement was to promote afforestation. According to data from the Ghana Statistical Service, Ghana Living Standard and a sample of 8,262 households in Mensah and Adu in 2013, 89.2% use biomass as their primary cooking source, while the rest depend on modern energy.

According to the breakdown, 56.1% of households use firewood, 31.9% coal, 1.2% use agricultural waste for cooking, 9.9% use LPG and kerosene, and electricity is reduced 0.6% and 9.9% respectively use LPG and kerosene. (Mensah & Adu, 2015). Unlike urban households, which depend on coal, kerosene, LPG and electricity, people in rural areas are more dependent on firewood and crop residues. When a Probit model was used to examine variables influencing household energy choices, it was found that household size, age of household head, and male household head all had significant negative effects on household energy consumption. likelihood of using clean energy and productive fuels instead of inefficient fuels. (Mensah & Adu, 2015). The literature that is now accessible indicates that Ghana has a high energy demand, with electricity and firewood making up most of that demand. And the best way to achieve so is to support afforestation and diversify into other resources.

2.5 Energy Consumption in Ghana

One of the few areas that Ghanaian scientists have given much thought to is energy consumption. Usually, energy demand and consumption are analysed together. In Ghana from 1971 to 2007, Kwakwa (2012) examined the links between overall growth, agricultural production and growth in production and disaggregated energy consumption (consumption of electricity and fossil fuels). Kwakwa (2012) a. He pointed out that little is known about Ghana and that consumer research is mainly conducted outside Africa. Again, the few studies done in Ghana have produced conflicting results on overall growth and electricity. In addition to electricity, fossil fuels make up a significant part of a country's energy consumption. The results show that aggregate growth determines the consumption of electricity and fossils rather than the use of electricity and fossil fuels that drive aggregate growth.

Appiah (2018) examined the causal interdependence between energy consumption, economic growth, and CO2 emissions in Ghana from 1960 to 2015 using the Toda-Yamamoto and Granger causality tests. This study examined whether long-term causal relationships existed between Ghana's economic growth and energy consumption between 1960 and 1965. Ghana's energy mix should include more renewable energy sources to reduce the country's over-reliance on imported fossil energy. Political support may require the application of financial explanations and regulations to stimulate and attract investment in renewable energy projects. There is a Granger-backward causal relationship between energy consumption and CO2 emissions, according to causality tests. Any energy saving policy that is not based on energy efficiency and technical progress can harm the Ghanaian economy as there is a relationship between energy consumption and economic growth as well as the impact on CO2 emissions. (Owusu, 2018).

2.6 Waste and Renewable Energy

The generation of biogas or biomethane opens the door to a society where resources are used and reused continuously, where the growing demand for energy services can be met by offering greater environmental benefits. (International Energy Agency (ESIO), 2020). The latest global trend to prevent it from decomposing due to waste created by living creatures is the use of trash as renewable energy. The health of the population and the environment are seriously threatened by the constantly changing quantity and quality of waste. (Rufis Fregue and colleagues, 2021). Municipal solid waste generation presently totals about 2.01 billion tons worldwide; by 2050, that number is projected to rise to almost 3.4 billion tons. Along with others, Luis Alberto Bertolucci Paes (2019).

Currently, only 2% of the materials are recycled and processed. Neumann et al, 2021). To prevent carbon emissions from damaging the climate and to help meet the world's energy needs by increasing energy consumption, waste management for energy production has been a major effort in most of the world. As a low-carbon energy source, the agricultural biogas sector now can become a major player in the new energy deal. (Mamica et al., 2022). To realize the full potential of renewable energy sources, research on renewable energy is essential. Kale 2016 explored some recent developments in renewable energy in her book Renewable Energy Systems. The book contains four chapters, one of which is about sustainable energy. The book examined many sustainable development concerns as well as potential applications for renewable energy technology. His discussion of the latest technological advancements in this field reflects his more than 10 years of experience in the industry. (Kale, 2016). The ever-increasing global need for energy is mostly met in part by renewable energy sources.

The World Energy Council claims that schedule-based refuelling can be utilized as a backdrop for the generation of renewable energy. Major renewable energy sources include solar photovoltaic conversion technologies, biomass and biofuel systems, wind turbines, geothermal energy technologies, and hydroelectric power systems. They argued that investing in renewable energy can both promote technological advances and reduce a country's reliance on importing fuel and purchasing energy from foreign markets. This article has focused on renewable energy technologies in Nigeria. The framework for the study was created using suggestions to address a range of socio-political, technological, financial and legal issues that need to be addressed if the nation is to effectively promote renewable energy. (World Energy Council, 2013).

Additionally, Kothari et al. (2010) examined in their article probable future energy usage patterns and their effects on the environment, prospective solutions to present environmental issues, and renewable energy technologies and their connections to sustainable development focused on waste-to-energy processes They clarify the world's problems and possible solutions. He called for diversity because he stressed how fossil fuel depletion and population growth will increase demand and consumption. They found that, despite its drawbacks, WTER has been promoted as a viable substitute for high-energy fossil fuels, such as anaerobic digestion and biological energy production. (Kothari et al., 2010).

2.7 Waste Management in Ghana

Waste management has always been a problem in Ghana. The country's governments and business sector have made great strides in waste management, but to no avail. This is because waste is disposed of carelessly and there are no reliable national statistics on waste generation and composition that Ghana could use to plan for effective waste management. (Miezah et al., 2015). Attempts have been made by certain Ghanaian researchers to understand how the public and commercial sectors try to manage garbage in Ghana.

In the Journal of Garbage Management, Miezah et al. presented an in-depth survey on waste management in Ghana in 2015. To gather information on waste generation rate, physical composition of waste, effective sorting and separation and waste per capita, they recruited households in each region. Statistics show that Ghana produced 0.47 kg of waste per person per day, or about 12,710 tons of waste per day, out of a population of 27,043,093. (Miezah et al,2015). These researchers used excellent data collection and analysis techniques. It was crucial that the authors had a solid understanding of Ghanaian garbage and waste management. An introduction to waste and trash management in Ghana is given in the article. Ofori Boateng et al. (2013) looked at the entire municipal waste produced in Ghana in 2010 and found that 90% of it is not disposed of properly, but is instead dumped on undeclared sites, thus harming human health.

Ghana is expected to face serious waste management problems due to its population growth rate, which is around 3.4% per year. Energy disposal plants can properly dispose of solid waste by recovering its powerful energy. (Ofori-Boateng et al., 2013). In order to put an end to the deterioration of the environment, they pleaded for the construction of waste management factories. This study analysed the root causes of efficient solid waste management in the city of Tamale and proposed workable solutions. The data was collected through preliminary research, research with questionnaires and personal interviews. The study found that waste management facilities lacked the resources to effectively collect the waste generated, waste storage was inadequate, waste was collected regularly, and waste disposal techniques were inadequate. The study proposed enough containers, frequent garbage collection and the introduction of integrated waste management considering the above problems. (Puopiel, 2010).

2.8 Anaerobic Digestion

Anaerobic digestion has been thoroughly investigated by numerous researchers, each of whom has given a unique definition. There are however some ideas that challenge categorization. Anaerobic digestion is the process by which microbes break down organic matter in the absence of oxygen. This is a normal process that occurs in lakes and soil. He went on to say that some waste digesters can use the same procedure. The fermentation product is a combination of gas that typically contains methane and can be used to produce heat and electricity. (Breeze, 2018). Additionally, Rogoff and Screven described anaerobic digestion as the breakdown of organic waste by bacteria without the use of free oxygen, with biogas as the primary by-product, a combination consisting primarily of methane and carbon dioxide. (Rogoff & Screve, 2011). The meaning of this definition is the same as that of Breeze.

A biological degradation process that takes place without oxygen is called anaerobic digestion. Degradation of organic matter is a multiphase process involving parallel and serial reactions such as methanogenesis, acidogenesis, acidogenesis, hydrolysis and acetogenesis. (Lohani & Havukainen, 2018). Anaerobic digestion occurs naturally in anaerobic environments such as the bottoms of ponds and swamps, wetlands, ruminant digestive tracts, and some insect digestive tracts (Paul Dobre et al., 2014). According to the criteria stated above, anaerobic digestion occurs in the absence of oxygen but in the presence of microorganisms. The process creates energy that can be used for a variety of purposes, including generating electricity and cooking gas. The graph below shows the phases of anaerobic digestion:

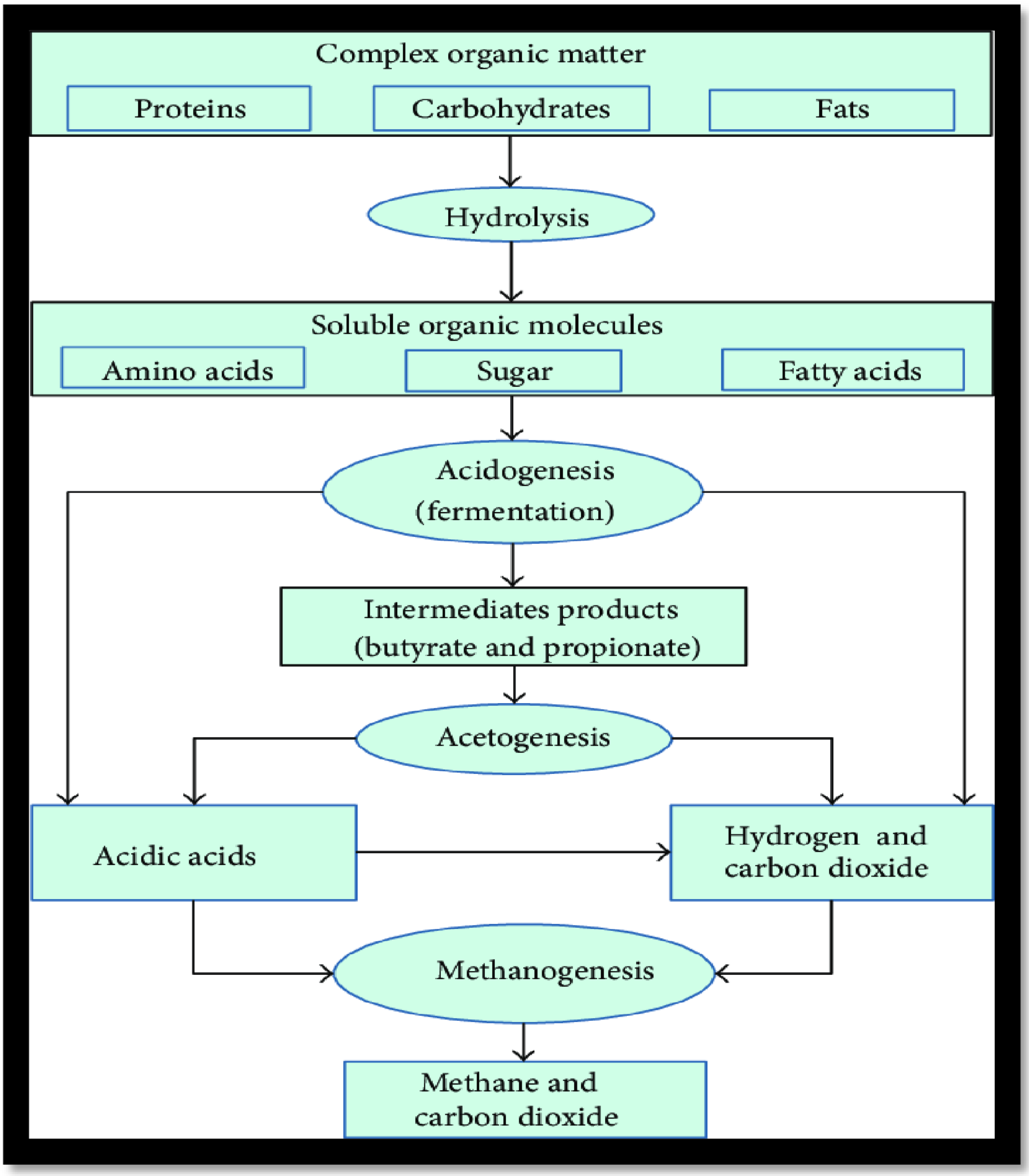

Figure 2: Schematic Diagram of Anaerobic Digestion

2.8.1 Factors affecting anaerobic digestion.

Each step of the anaerobic digestion process can be influenced by several variables. While some of these features may go unnoticed, others have already been discovered. Waste with a high moisture content is best suited for digestion, landfill, and anaerobic digestion technologies. (Abanades et al 2022). The redox state of the organic matter, its biodegradability, and the type of AD process used all affect the composition of the biogas. (Iglesias et al. 2021). Many variables affecting anaerobic digestion have however been identified, according to Dobre et al. the substrate and the temperature of the anaerobic digestion process are the main variables. (Paul Dobre et al., 2014). They added that, in addition to temperature, the C/N ratio and the sub-pH layer's level are two additional factors that can affect how microorganisms react to the raw material's amount of biodegradable organic compounds. (Paul Dobre et al., 2014).

By analysing prior work, Chen et al. also looked at the mechanisms that prevent anaerobic digestion. They prioritized garbage because they think it has a big impact on how much biogas is produced. They claim that a lot of agricultural and industrial wastes make excellent anaerobic digestion candidates since they contain a lot of easily biodegradable components. Inhibitors that are frequently found in anaerobic digesters include ammonia, sulphide, light metal ions, heavy metals, and organic compounds. As a result of variations in anaerobic inoculums, waste composition, experimental methodologies, and settings, literature results on inhibition by toxicants are widely dispersed. Including elimination or control techniques, microbial adaptation to inhibitory substances and circumstances, and co-fermentation with other wastes.

2.8.2 Biogas Formation

Hydrolysis: Enzymes are secreted by microorganisms that break down organic materials like carbohydrates, lipids, and nucleic acids into smaller units like glucose, glycerol, purines, and pyridines. The hydrolysis of a particulate or macromolecular substrate into soluble monomers is catalysed by enzymes formed from the soluble products that feed the species. Hydrolytic bacteria's primary mechanism involves binding the organism to a particle to produce enzymes and then using the enzyme secretion to break down organic matter into smaller units (Deublein & Steinhauser, 2011).

Acidogenesis: Acetate, carbon dioxide, hydrogen, and volatile fatty acids are hydrolysed by bacteria to create fermentation. Anaerobic acid-producing bacteria create fermentation known as acidogenesis. The method entails breaking down soluble sugars and amino acids into simpler products like acetate, propionate, butyrate, lactate, and ethanol. The concentration of H_2 and the pH values determine the proportion of organic products produced by acid-forming bacteria. Propionic acid production predominates at higher hydrogen content, resulting in neutral pH values. When the pH becomes acidic, however, the production of butyric acid begins to predominate (Deublein & Steinhauser, 2011).

Acetogenesis: Before being converted to methane, volatile fatty acids and alcohols are oxidized to acetate, hydrogen, and carbon dioxide. This process is linked to methanogenesis. Organic acid oxidizers use extra hydrogen ions to produce H_2 gas, CO_2, or both.

Methanogenesis: Methane is produced by specialized single-celled microorganisms (archaea) from acetate, hydrogen, and carbon dioxide. The ability of methanogenic bacteria to convert carbon dioxide to methane is critical to their survival. About 70% of the methane produced comes from acetate, with the remaining 30% coming from hydrogen and carbon dioxide conversion. Methanogenesis is an important step in the biogas process because it is the slowest biochemical reaction step for producing methane. When the methanogenesis process is stopped, acidification occurs, resulting in a low biogas yield. Operating conditions such as starting material, feed rate, temperature, and pH all have an impact on this step (Deublein & Steinhauser, 2011). Toxins before anaerobic digestion can greatly improve waste treatment efficiency. Chen and colleagues (2008).

2.8.3 Feedstock

Any renewable biological material that can be used directly as a fuel or converted into another type of fuel or energy product is considered a feedstock (Kataki et al., 2015). Carbohydrate polymers (cellulose and hemicellulose) and phenolic polymers dominate the raw materials (lignin). Many other compounds, such as proteins, acids, salts, and minerals, are also present in lower concentrations. Cellulose and hemicellulose are polysaccharides that can be hydrolysed into sugars and then fermented into ethanol. They typically account for two-thirds of the dry matter of the cell wall (the portion of the biomass that is not water) (Speight, 2011). Raw materials derived from plants are at the heart of biorefineries and the circular bioeconomy.

As raw materials for bio refineries, a variety of raw materials have been proposed, ranging from designated energy crops to agricultural residues and various waste streams. The utilization of waste raw materials in biorefineries has both positive and negative implications. Waste raw materials are frequently available at low cost, providing an additional incentive for use in biorefineries (Pandey et al., 2019). In Ghana, there are vast biomass resources, including organic waste, that could be used as feedstock for biogas production, reducing reliance on wood fuel and fossil fuels and, as a result, lowering greenhouse gas emissions. greenhouses that provide food for the environment impact climate change (Arthur et al., 2011c).

2.8.4 Digestate

Digestate is a nutrient-rich by-product of anaerobic digestion that can be used as a fertilizer. It is composed of indigestible material remnants and dead microorganisms; the amount of digestate is approximately 90-95 percent of what entered the digester. Digestate is not compost, despite having similar properties. Aerobic microorganisms produce compost, which means they require oxygen from the air to function. Anaerobic digestion digestate can be recycled and used as fertilizer to grow vegetables for sustainable agriculture. They contain a lot of nutrients like nitrogen and phosphorus.

2.9 Biogas Digester Design

Fixed dome and floating drum biogas plants are the most widely advertised in Ghana, and many installers have installed them. These stoves influenced the design and implementation of the four most popular models in the region, including the B. Fixed Dome, CAMARTEC, Puxin, and Deenbanhu. However, the Anaerobic Puzzled Reactor has been used since the 1990s and is now being promoted (Bensah et al., 2010).

2.9.1 Types of Designs

The digester shown below is one of the most widely used biogas digesters in Ghana. The benefits of these fermenters include low construction costs, no moving parts, no rusting steel parts, a service life of more than 20 years, job opportunities for local craftsmen, and relatively constant fermentation temperature for optimal production. The disadvantages of these fermenters include fluctuating gas pressure, i.e., high, or low gas pressures, a small crack in the upper masonry can result in large biogas losses, and low digester temperatures (Abbasi et al., 2012; Fulford 1988; Sasse, 1998). There are skills and expertise in Ghana to manage small and medium-sized biogas digesters, but there is limited expertise on an industrial scale in terms of design, installation, operation, and maintenance of biogas digesters factories. Edward A. Awafo and Victor K. Agyeman (2020).

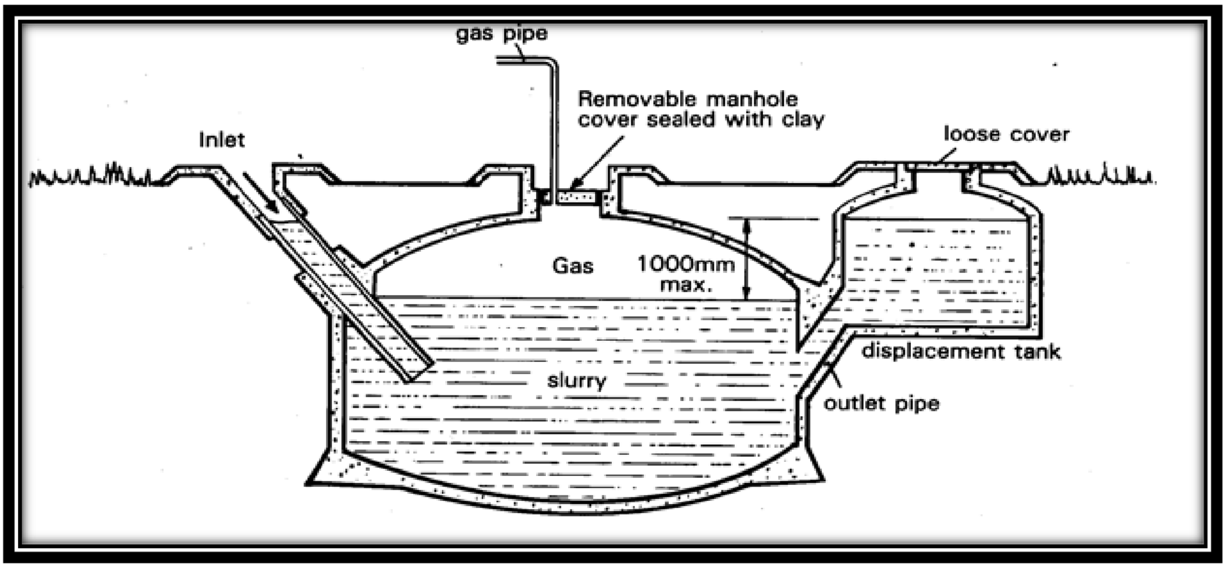

Figure 3: Fixed Dome, Source: (Bansah et al, 2010)

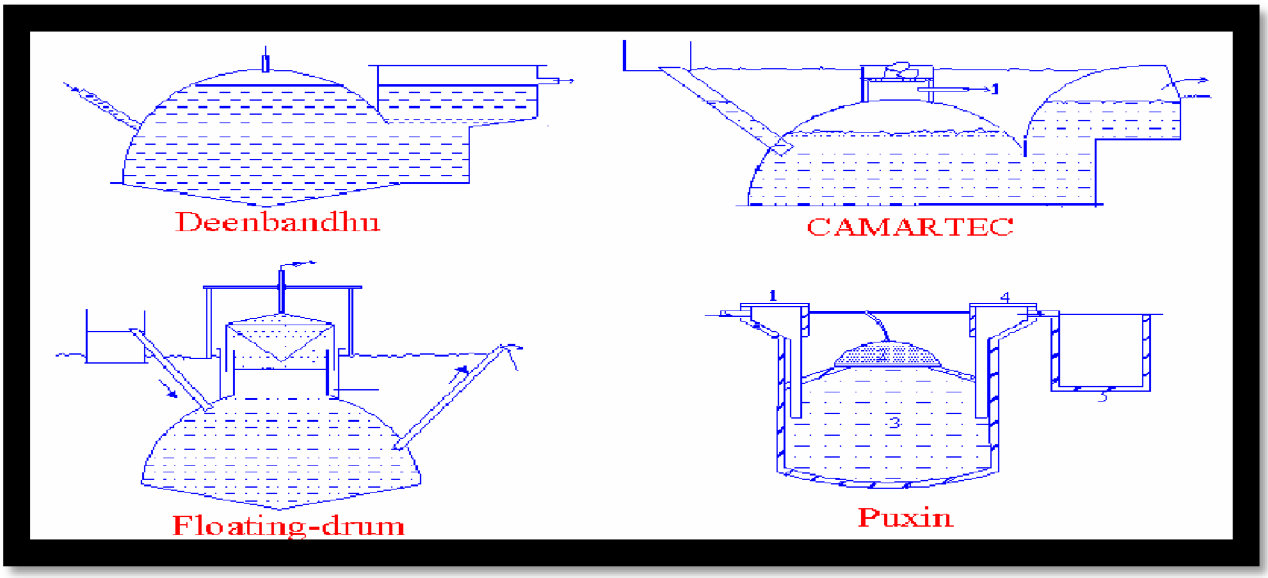

Figure 4: (Digesters widely constructed in Ghana. Source: Bensah et al.2011)

2.10 Historical background of Biogas in Ghana

In Ghana, the use of renewable energy sources such as biogas began in the 1980s (Arthur et al., 2011a) (EC Bensah & Brew-Hammond, 2010). After years of meeting renewable energy sources, Ghana's government and private sector have done little to promote and use renewable energy as a supplement to our energy industry. The Ministry of Energy built the first biogas demonstration plant in 1986 at the Shai Hills livestock farm in the Greater Accra region, with Chinese government assistance.

The United Nations Children's Fund (UNICEF) supported the construction of a series of domestic biogas demonstration plants in Jisonayilli and Kurugu in the northern region a year later, in 1987. (EC Bensah & Brew-Hammond, 2010). The Energy Commission (EC) was established in 1997 to develop, regulate, and manage the country's renewable energy sources. The established EC did its best, but it was in vain. To increase the country's use of renewable energy, the Energy Commission, in collaboration with the national strategic power plant, has issued a programmatic document that defines the role of the various energy sources, with a goal for each within the next twenty years (Arthur et al., 2011a). Despite these efforts, the process was slow.

2.10.1 Status of Biogas technology in Ghana

After years of government and private sector efforts, the country's biogas situation is meaningless. A survey of 50 biogas plants was conducted in 2010 to determine the true state of biogas technology in Ghana. Between June 2008 and February 2009, field visits to biogas plants were conducted. There has been some progress in the use of biogas, but it has been slow. The relatively high number of installations distributed between 2001 and 2009 can be attributed to John Idan's founding of BTWAL, Ghana's largest biogas company, in 2000. (E. C. Bensah & Brew-Hammond, 2010).

Ghana's biogas industry is still in its infancy; while Ghana has built slightly more than 250 biogas plants, sister countries Kenya and Tanzania have built over 2000 and 5000 plants, respectively (E. Bensah et al., 2011). According to Bansa et al, biogas has significant potential as a source of energy for households as well as a commercial enterprise. However, most Ghanaians perceive it differently and regard it as a luxury. Ghana's use of biogas is very low, and the government should pay special attention to its people (EC Bensah & Brew-Hammond, 2010).

2.10.2 Biogas Technology and the SDGs

The United Nations created the Millennium Development Goals, which are eight goals that all 191 UN member states have agreed to strive for by 2015. The Millennium Declaration of the United Nations, signed in September 2000, requires world leaders to reduce poverty, hunger, disease, illiteracy, environmental degradation, and gender discrimination. The MDGs are derived from this Declaration, and each has its own set of goals and indicators.

The Eight Millennium Development Goals are:

1. To eradicate extreme poverty and hunger.
2. To achieve universal primary education.
3. To promote gender equality and empower women.
4. To reduce child mortality.
5. To improve maternal health.
6. to combat HIV/AIDS, malaria, and other diseases.
7. to ensure environmental sustainability, and
8. to develop a global partnership for development.

The Millennium Development Goals were dropped from the list of Sustainable Development Goals. The Millennium Development Goals and the Sustainable Development Goals are linked. In today's world, achieving "sustainable development" is a huge challenge. These are technologies that can assist in managing growth while keeping societies economic, social, and environmental sustainability in mind. (2016) (Alayi et al.). The need to promote developments that meet today's and tomorrow's needs has become a critical issue for our survival and that of future generations. As a result, biogas solutions can help to achieve many UN sustainability and development goals. Gustafsson and Anderberg (2002)

Energy, an important component of modern economic development, must be weighed against other aspects of development. Biomass can be used to provide a sustainable source of energy in the form of biogas, vegetable oil, biodiesel, producer gas, and direct combustion of biomass. In 2015, 193 world leaders convened to develop an agenda and action plan for people, planet, and prosperity. They also attempted to promote global peace. This meeting resulted in the adoption of 17 Sustainable Development Goals and 169 targets. The following are the relevant Sustainable Development Goals for this study:

Table 1 : ***SDGs and Contribution to Anaerobic Digestion*** **(Globalgoals.org)**

	GOAL	TARGET
Goal 02	Ensure food security, improve nutrition, and support sustainable agriculture to end hunger.	Recycling nutrients, organic matter, and carbon for soil remediation. Use of nutrient-rich organic fertilizers for digestate to increase crop yields. Recirculation of phosphorus, necessary for plant growth but rare
Goal 03	Ensure healthy lives and promote well-being for all at all ages	• Reducing indoor air pollution by substituting solid biomass-based domestic fuels with biogas • Treating and recycling sewage and organic wastes to reduce odours and the spread of diseases
Goal 05	Achieve gender equality and empower all women and girls	• Reducing the burden of collecting firewood to improve the quality of women's and children's lives, reducing household labour in cooking.
Goal 06	Ensure availability and sustainable management of water and sanitation for all	• Providing decentralized, local treatment of bio-solids in remote and rural communities to reduce odours and the spread of disease • Stabilising and recycling biosolids through AD to allow them to be applied back to the land • Reducing the carbon loading of wastewater to reduce the impact on water bodies

Goal 07	Ensure access to affordable, reliable, sustainable, and modern energy for all	• Capturing waste heat from co-generating units linked to biogas plants • Utilising locally produced wastes and crops to generate energy for rural and remote communities • Storing biogas to produce energy when required
Goal 09	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	• Improving the self-sufficiency and sustainability of industries by extracting the energy from their effluents and using it for the self-generation of electricity and/or heat • Collaboration between industries and agriculture for mutual benefit • Generating short-term construction employment and long-term equipment manufacturing and maintenance employment • Encouraging growth of micro-enterprises by providing reliable electricity that can be stored and used when needed, i.e., baseload energy
Goal 11	Make cities and human settlements inclusive, safe, resilient, and sustainable.	• Preventing the spread of diseases through the collection and proper management of organic waste • Improving sanitation and hygiene through decentralized and local treatment of biosolids • Stabilising the sludge from wastewater treatment to protect the marine environment and urban air

		quality • Improving urban air quality by substituting fossil fuel with biomethane in vehicles • Improving urban air quality by substituting solid fuel for domestic cooking and heating with biogas • Reducing greenhouse gas emissions by using biogas-based renewable energy in buildings, homes, and industry.
Goal 13	Take urgent action to combat climate change and its impacts.	• Reducing carbon dioxide emissions by replacing fossil-fuel-based energy sources with biogas and commercial fertilizers with digestate biofertilizers • Reduction of methane and nitrous oxide emissions from livestock manures • Reduction of methane and generation of renewable energy from food and other organic wastes • Capturing emissions from landfills • Reducing deforestation by replacing solid-biomass-based domestic fuels with biogas
Goal 15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss	• Recirculating nutrients and organic matter in organic wastes through AD and returning them to the soil in the form of digestate biofertilizer • Substituting firewood with biogas as a domestic fuel, reducing deforestation

2.11 Potentials and Benefits of Biogas in Ghana

Biogas has enormous potential and has benefited the world in numerous ways. Biogas is primarily used to generate thermal energy and electricity. Salehi and Chaiprapat (2002) It has aided the world in diversifying its energy sources in a sustainable manner while causing minimal environmental damage. According to E Bansah et al. (2011), establishing a large-scale biogas program in Ghana will improve sanitation, generate clean energy, reduce greenhouse gas emissions, promote nutrient recovery, and create jobs (E Bensah et al., 2011). The biogas industry is expanding, and new technologies are being developed to keep up with the growing number of plants in operation. Lieberau et al. (2017).

Furthermore, many biogas service providers in Ghana are skilled artisans, demonstrating (Smith 2011) that biogas technology creates jobs and improves the livelihoods of the local population (including artisans who can be trained to build digesters). Since IRENA's first jobs report in 2012, renewable energy employment has been on the rise (International Renewable Energy Agency, 2021). According to Bensah et al. (2011), the first phase of biogas technology development in Ghana involved training local engineers and technicians in the design, construction, and management of biogas plants through a government-sponsored project (Osei-Marfo et al., 2018). The above benefits of biogas in the country can be projected if it becomes widely used and accepted in the country.

The quantification of greenhouse gas (GHG) emissions and environmental impacts of biogas production provides an important foundation for designing future biogas production subsidies while minimizing GHG emissions and environmental impacts. 2021) (Jørgen E. Olsen et al).

2.11.1 Disadvantages of Biogas

Biogas is a complex technology that is not widely used in developing countries like Ghana due to factors such as high initial costs, high maintenance costs, a lack of knowledge or awareness, and the promotion of inexperienced technicians. These restrictions, among other things, have slowed the adoption of biogas in Ghana. According to Doghle, the price of a digester in Ghana ranges from GH5,000.00 to 10,000.00 depending on the size, nature of the soil (watery or rocky), and other factors (Doghle, 2018). Another disadvantage of biogas is that industrial biogas plants are only viable if raw materials are abundant (food waste, manure). As a result, biogas generation is better suited to rural and suburban areas. (Khayal, 2019).

2.12 Policies promoting the use of Biogas in Ghana

The Ghanaian government has paid little attention to the biogas industry and has issued no policies to support it. Biogas technology is deceptively simple in concept, and raw materials are plentiful (Karekezi 2002). However, many projects have been ineffective or have run into problems soon after they were launched. This is due to African governments' inability to support the technology through targeted energy policies (Osei-Marfo et al., 2018). The Ministry of Energy established one of the first large-scale municipal biogas demonstration projects in Ghana in 1986 as the "Integrated Energy and Rural Environment Project" (Arthur and al., 2011b) in Appolonia, Accra, through which 19 small household fermenters were installed. This was done to increase the use of biogas in the country. The Ghanaian government, through the Ministry of Energy, commissioned the first large-scale community biogas plant at Appolonia in June 1992. The Appolonia Integrated Rural Energy Project aimed to provide all households in the community with street lighting and electricity for small appliances.

The Energy Commission (EC) was established in 1997 to develop, regulate, and manage the country's renewable energy sources. The European Commission created the Strategic National Energy Facility in 2006, a policy document that defined the role of various energy sources and set a target for each within the next twenty years (E. C. Bensah & Brew-Hammond, 2010). We have shortened the time it takes to reach the stated goal by half, but there has been no significant improvement in the use of biogas in Ghana. In short, there is a scarcity of literature on biogas and environmental sustainability in Ghana, and few scientists have devoted time and attention to studying it thoroughly. However, few scholars have studied it and done an excellent job of revealing its status, tracing its history from its inception, and demonstrating its significance both for its potential and for its potential in this era.

3.0 RESEARCH METHODOLOGY

3.1 Awutu Senya East Municipality

One of the recently established districts in Ghana's Central Region is Awutu Senya District, which was transformed into Awutu Senya East Municipality in 2012. The municipality is bordered to the south by Gomoa East District, the east by Ga South District, and the west by Awutu Senya West District. The municipality's administrative headquarters are at Kasoa, which is a suburb southeast to Accra. It is 31 kilometres away from Accra. Awutu Senya East Municipality contains 108,422 residents, which represents 4.9 percent of central Ghana's total population, according to the 2010 census. Males make up 48.1% of this population while females make up 51.9%. 94.1 percent of the overall population lives in urban areas, while 5.9 percent lives in rural areas (Ghana Statistical Service, 2014). According to the 2010 population and housing census, the municipality has a young population (38.3) and a small proportion of old persons (2.4 %). The local economy of the community is thriving. Trade (retail and wholesale), agro-industry, trade, and informal sector services are the primary industries. Finally, the informal private sector contributes significantly to the local community economy, employing around 81.9 percent of the working population. Significantly, most people in the municipality use public WCs and KVIPs. This represents 39.5% of households. It is followed by 23.1% of households that use a pit latrine. Sadly, about 15.5% of the entire population in the municipality has no toilet facilities for use (Ghana Statistical Service, 2014).

According to the 2010 census data, coal is the primary fuel for cooking in 54.3 percent of Awutu Senya East municipality homes. Gas is the second most frequent source, accounting for 34.3 percent of home cooking fuel usage. Wood fuel accounts for 5.7 percent, with animal waste and agricultural leftovers accounting for the remaining 0.1 percent. Again, coal is more prevalent in urban and rural homes, accounting for 55% and 43.3 percent, respectively. Gas is still the second most popular cooking fuel among urban families. In rural families, however, firewood outnumbers gas cooking by 36.8 percent (Ghana Statistical Service, 2014). For cooking, gas is widely utilized in urban families, whereas wood is mostly used in rural communities.

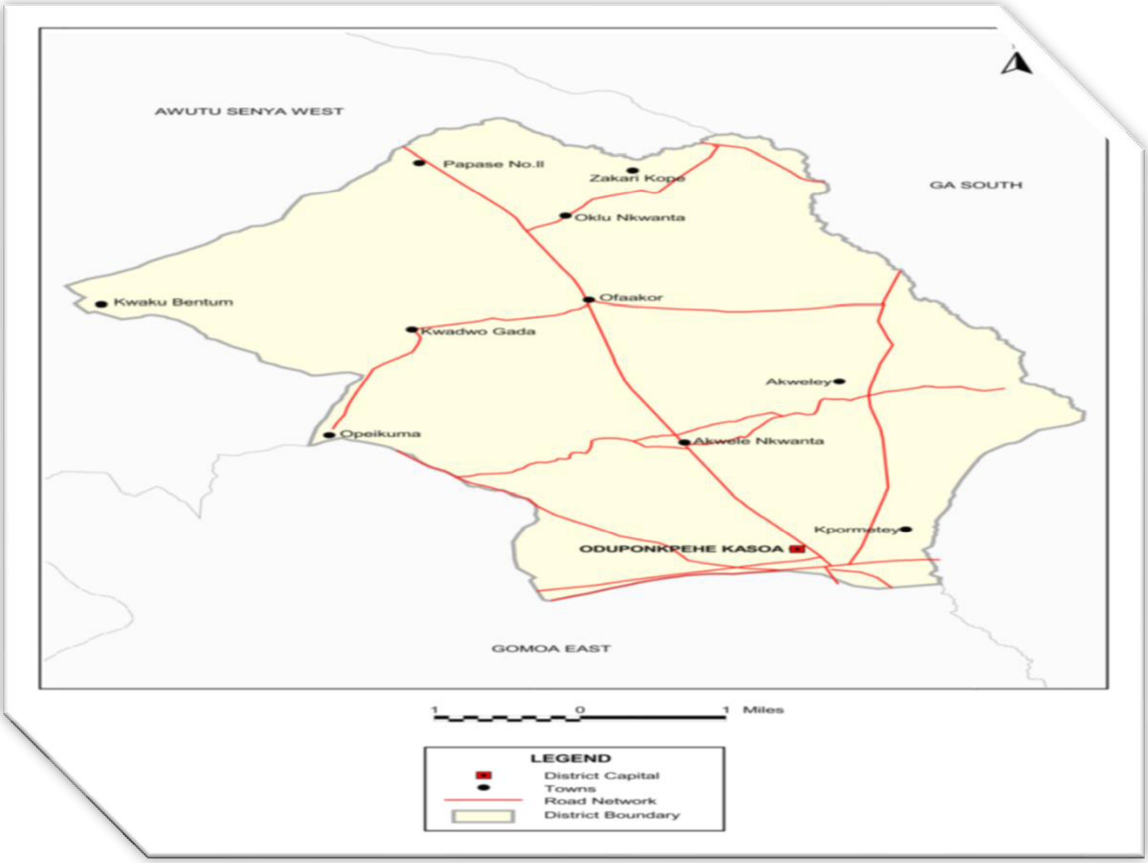

Figure 5: Map of Awutu Senya East Municipality Source: GSS (2014)

3.2 Effutu Municipality

The central region of Ghana has twenty administrative districts, including the municipality of Effuttu. It is in the east of the region, between latitudes 5 ° 16 'and 20.18 "N and longitudes 0 ° 32' and 48.32" W. Winneba is the administrative capital of the municipality. The capital is known for its extensive educational facilities. The capital is surrounded by fourteen other villages. The municipality has a total area of 95 square kilometers. According to the 2010 Ghana Population and Housing Census, the municipality of Effuttu has a population of 68,597 people, with 33,612.5 (49%) males and 34,984.5 (51%) females. This figure represents 3.1 percent of Ghana's total population in the central region. The 2010 census shows that 93.3 percent of the total population of the municipality lives in these urban areas, the highest percentage in the entire central region.

The municipality's local economy is made up of a variety of key economic activity. Fishing, salt production, wholesale and retail commerce, agriculture, and agro processing are among them. Fishing and arable farming continue to be the most prominent economic activity in the municipality (Ghana Statistical Services, 2014). First, fisheries are widely established in nearby coastal areas like as Warabeba, Winneba, and Akosua Village (Ghana Statistical Services, 2014). Charcoal is the main source of cooking fuel in the Effutu Municipality. The 2010 census of population and housing indicated that 49.1% of households use charcoal in cooking. The next dominant source of cooking fuel is LPG which has an indication of 26.9% followed by kerosene (1.0%). The least source of cooking fuel is animal waste, which has 0.1% of households using it, although 52.2% of households are involved in livestock rearing (Ghana Statistical Service,2014).

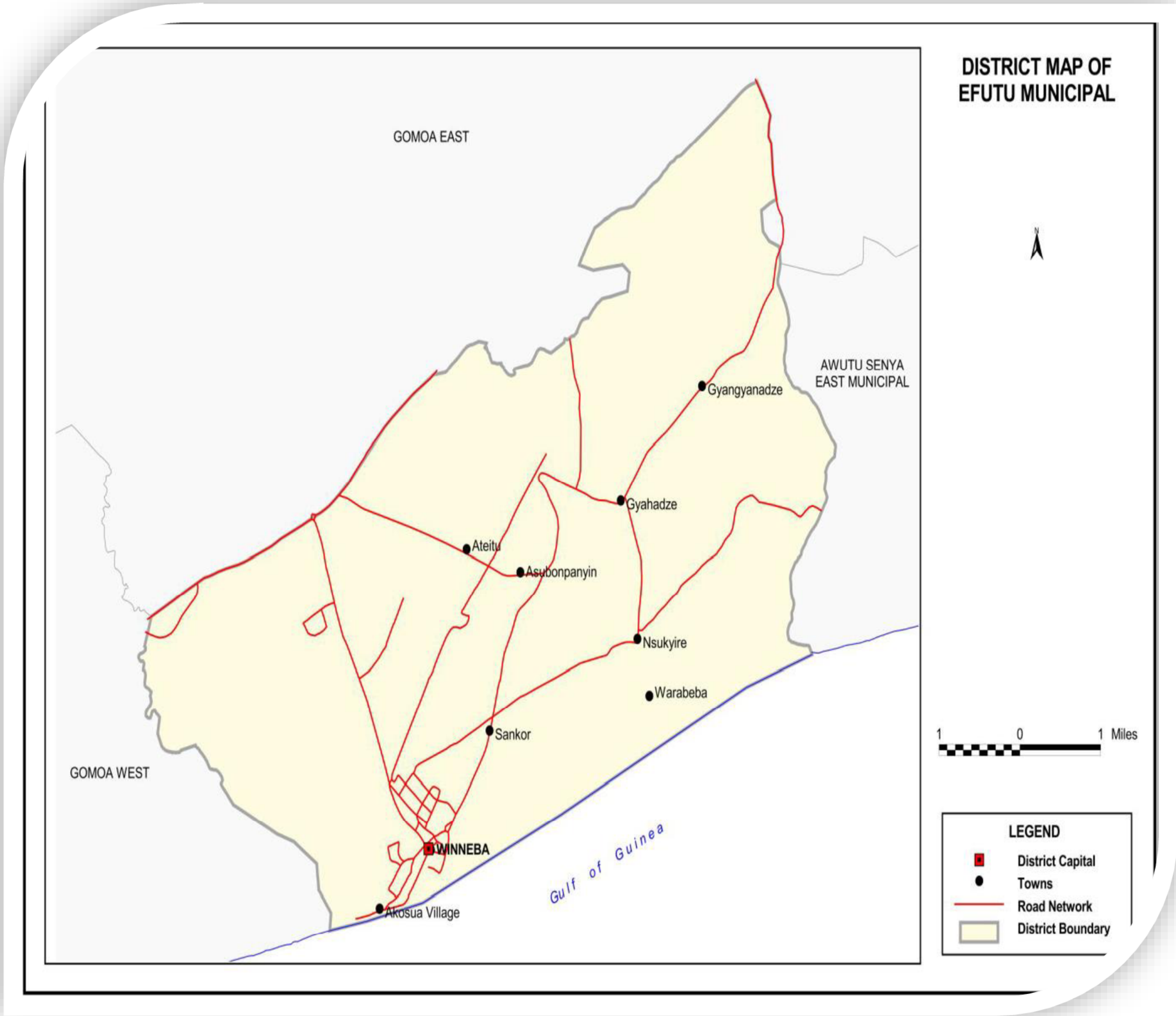

Figure 6: Map of Effutu Municipality Source: Ghana Statistical Service (2014)

3.3 Research Methodology

Research is a way to solve difficult problems to overcome the limits of human ignorance (Leedy, 1980). According to Kothari (2003), research is a systematic method of finding solutions to research problems, defined as the search for truth through investigation, observation, comparison, and experimentation. Kothari (2003) further explains that the inquiry process is a systematic method that includes the following in a logical order:

a) Enunciating or defining the research problem.

b) Formulating the research questions from the research problem.

c) Designing the appropriate research process.

e) Analysing the data

f) Reaching certain conclusions from the analysed data, hence answering research questions

On the other hand, research methodology is inclusive of the research methods and comprises the overall approach to the research process from definition to selection of the appropriate research method and analysis of data and concluding the analysis. Hence the process would entail all the steps proposed by Kothari (2003) above.

3.4 Research Design

To evaluate how well biogas would replace the solid fuels now utilized in rural and suburban households, both quantitative and qualitative methodologies have been applied. Accordingly, a mixed research design was employed. We were able to get specific data using this technique, which helped us reach our study goals.

3.5 Data Requirements

As was already said, the purpose of this project is to investigate the advantages and drawbacks of employing household biogas technology in Ghana as well as the possibility for biogas to replace the solid fuels now utilized in rural and suburban houses. It (a) evaluates the family's knowledge and awareness of the use of biogas and wood fuel technologies; (b) calculates the socioeconomic, health, environmental, or climate impact of each household's use of wood fuel-related biogas technology; and (c) identifies the main obstacles to the adoption of home biogas technology. d) Calculate the percentage of organic waste that can be utilized to provide cheap, dependable, sustainable, and contemporary energy. (e) Examining Ghana's government's initiatives to encourage the use of clean and renewable energy once the SDGs are accomplished. In general, these requirements affected the kind of data gathered. Variables are a characteristic that may have changing values, according to Kerlinger (cited in Kumar 1999 in 1986).

Table 2: Data Requirements of the Study

Research Objective	Variable(s)	Source	Tool
Assessing the level of awareness and knowledge of households regarding the use of wood fuel and biogas technology.	• Installed fermenter. • installed fermenter type. • Who paid for the installation. • When was it completed. • Understanding the utilization of biogas. • The purpose for which the gas is used. • Gadgets that use biogas energy. • Feedstock used to produce biogas. • What energy source is used for lighting and cooking.	Heads of household	Interview schedule
Determine if houses that have adopted and use technology instead of firewood have socio-economic, health, environmental or climate benefits.	• Socioeconomic Evaluation. • Environmental Evaluation. • Health Evaluation.	Heads of household Local government	Interview schedule Interview guide
Identification of the main obstacles to the deployment and implementation of biogas technology.	• Advantages and Disadvantages of biogas compared to wood energy, • Agriculture is practiced, there are fixed pit latrines and water supply	Heads of household	Interview schedule
Examine the policies enacted by the Ghana Government following fulfilling Sustainable Development Goals that promote the use of clean renewable energy sources.	• Policies, initiatives, and approaches, • Participation of communities in the formulation of these policies and project sustainability.	Local Government NGOs Heads of household	Interview guide Interview schedule

3.6 Sampling

Families, local officials, and NGOs participated in the study. 320 households from two surveyed communities, four local officials and two NGOs participated in the survey. The sampling method used was a combination of objective sampling, simple random sampling, and convenience sampling. This allows us to collect useful information from our target audience. Criteria for selecting participants are as follows:

- Residents participate voluntarily.
- Participants that own livestock.
- A farming family.
- The resident is the owner of the pit toilet.
- Biogas-oriented NGOs actively participate in community projects aimed at improving community sustainability.
- individuals who have district-level positions that are acknowledged by local government.
- Availability of a reliable source of water supply.

Table 3 : Summary of Sample Size for Household Data Collection

District	**Community**	**Sample Size**
Awutu Senya East	Kasoa	100
	Ofaakor	50
	Opeikuma	30
		Total = 180
Effutu	Winneba	90
	Nsukyire	30
	Warabeba	20
		Total = 140
TOTAL		**320**

3.7 Data Collection Methods and Instruments

The study used two data collection devices from the original study. These were used as a guide for conducting interviews to collect qualitative data from local authorities and NGOs interested in biogas. In addition, an interview schedule was used to collect quantitative and qualitative data from the families. Other data collection methods include taking photographs in the field, recording sounds, and collecting relevant data for analysis using observational skills.

3.8 Data Analysis

Data analysis is a practical and comprehensive representation of how raw data is structured to provide useful information. Methods such as qualitative and quantitative analysis were used to analyze the data. Quantitative methods used tables, graphs, percentages, and textual assessments of data, while qualitative studies used descriptions, quotations, and figures. Cross-case studies were also conducted to explore concerns and gain new information.

Figure 3 shows a schematic representation of the Waugh (1995) data analysis and reporting process showing the main components of the analysis framework. As a result, the study approach and analysis method are summarized in Figure 3.3. Figure 7 shows the stages of the applied research technique.

FRAMEWORK FOR DATA ANALYSIS AND REPORTING

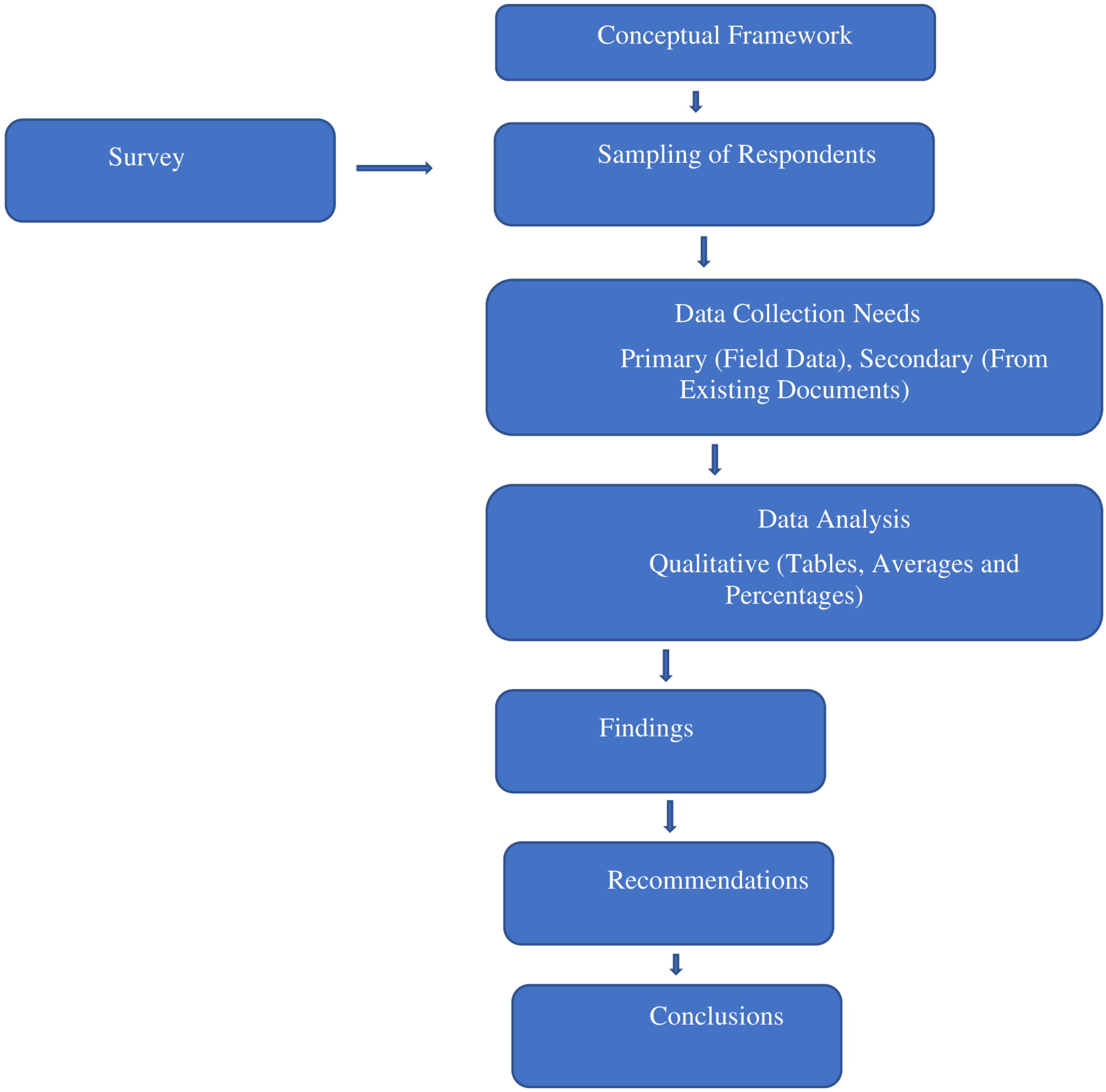

Figure 7: Framework for Data Analysis and Reporting

4.0 RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of Household Heads

The respondents' sociodemographic factors included their age, gender, educational background, and experience. The acquired data aid in the investigation of the association between home biogas adoption and socio-demographic characteristics in the research region. The study had 303 answers, with Awutu Senya East and Effuttu obtaining 149 (49%) and 154 (51%) replies, respectively.

4.2. Household Heads Gender Composition

Respondents are grouped into two gender categories: male and female. Males headed households accounted for 58 percent whereas female headed households accounted for 42 percent according to the gathered data. The cultural and social structure of the African society demands that men head homes and take decisions thus accounting for the data collated. Income broadens a leader's reach inside the family, but it is not sufficient to maintain the lead. Men and women are accountable for various areas of decision-making in households where at least one conjugal marriage is expected, according to evidence, reflecting the traditional gendered division of labour between production and reproduction. (Posel, 2001).

Table 4 : Sex of Respondents

Sex	Frequency	Percent
Female	127	42
Male	176	58
Total	303	100.0

4.2.1 Age of Household Heads

When undertaking a cross-fuel study of biogas and other household fuel sources, age is an important demographic component to consider. The survey's age range was separated into four categories: (21 to 30), (31 to 40), (41 to 50), (51 to 60), and above 60. Table 5 shows the percentage and frequency distribution of household members in the various categories.

Table 5: Age of respondent

Age	Frequency	Percent
21-30 years	57	18.8
31-40 years	84	27.6
41-50 years	125	41.3
51-60 years	35	11.6
Above 60 years	2	0.7
Total	303	100

Many responders were between the ages of 41 and 50. This age group had the most replies. About 19 percent of the population is between the ages of 21 and 30, and about 28 percent is between the ages of 31 and 40. The large number of 41-50 (41%) and 31–40-year-olds is attributable to Africa's and Ghana's high unemployment rates. As a result, this age group has working classes and employers. Another argument is that during economic downturns, young individuals are more vulnerable than older people owing to labor shortages, such as a lack of education and experience (Baah-Boateng, 2015). As a result of this condition, persons in this age group between the ages of 41 and 50 have the resources and capacity to make judgments on the implementation and utilization of biogas technologies.

4.2.2 Educational Household Heads

Education influences the structure of the population. Several studies have shown that a person's upbringing and exposure affect the judgments they make. The level of education used in the study corresponds to the level of education in Ghana. Progress in education in Ghana has been closely linked to socio-political developments since colonial times. Figure 8 shows the percentage of respondents by the level of education.

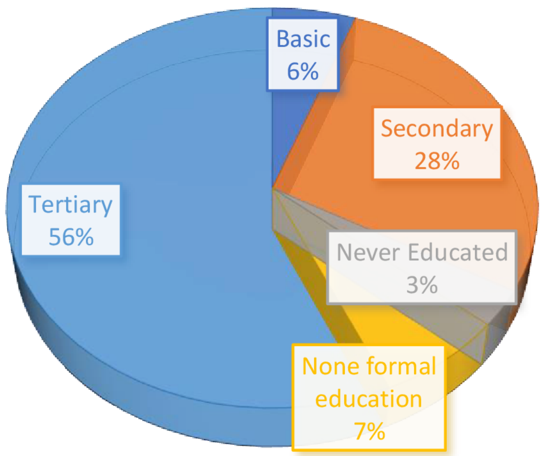

Figure 8: Level of Education of Household Heads

In the charts above, most household heads are highly educated, representing 56% of all respondents, while 3% have no education. The urbanity of the two communities from which the respondents come could explain the high proportion of higher education. Respondents in the survey region also have easy access to education in an easily accessible location. Between 1970 and 2010, education in sub-Saharan Africa expanded significantly, and the number of students completing primary school increased by approximately 50% across the continent (from 46% to 68% of children). Evans and Mendez Acosta (2002). Winneba, the district capital, has a legitimate state university and several secondary schools. Many of the inhabitants can read and understand the benefits of the adoption of biogas technology and the benefit to the environment, their well-being, and socio-economic existence.

4.2.3 Occupation of Household Heads

Individual economic actions have a huge impact on access to and control over resources. This study examines the various occupations of the respondents. According to Table

6, all heads of families surveyed are employed. The data shows the economic characteristics of the research community as an economic and commercial centre. In contrast, the majority of college graduates are categorized as administrative employees or other government employees, which is not the most common educational qualification (college education). Only 13 percent of respondents came from agriculture. This is because these community-based economic communities are commercial. Other vocations (17%) are said to be involved in a variety of businesses, such as students, food wholesalers, and artists with varying levels of experience.

Table 6: Occupation of respondent

Occupation	Frequency	Percent
Agriculture	40	13.2
Civil Servant	35	11.6
Commercial	178	58.7
Others Specify.	50	16.5
Total	303	100.0

It should be noted that biogas farms are inextricably tied to agricultural activity. As a result, we sought to discover what sort of agricultural property the respondents working in this industry possessed in our survey. Agriculture employs about 13 percent (40 respondents), with around 35 percent employed by people and 65 percent self-employed on farms.

4.3 Biogas and its Related Aspects

This part of the study includes data on several key variables that influenced the introduction and use of biogas energy identified for research purposes. These are the variables:

- Biogas availability in the residence, with 1 representing YES and 2 representing NO. The installed kind of biogas fermenter, with 1 representing fixed dome, 2 representing floating dome, 3 indicating Cylinder, and 4 representing others.

- Respondents' equipment's that relies on energy sources other than biogas.
- Commonly used feedstock/raw materials for biogas production and why.

The existence of biogas stations was used as an explanatory variable in the MANOVA test, which was used to study the effects of the introduction and diffusion of biogas technology on the achievement of sustainable development goals. The results in Table 7 show that of all the respondents who participated in the survey, 21% (65 out of 303 responses) of the respondents knew about biogas technology and had an installation at home compared to those who did not use biogas accounting for 79%. A very low number, to say the least.

Table 7: Availability of Biogas installation in households

Biogas Installed	Frequency	Percent
No	238	79
Yes	65	21
Total	303	100.0

Based on the information collected by the interviewees, the families choose to use only biogas technology with floating drums and fixed domes. This result is in line with the results of a study on the types of biogas technology adopted and used in Ghana (EC Bensah & Brew-Hammond, 2020). Discovery was made of the fact that fixed domes account for 91% of installed assets, whereas floating drums account for 9%. (See figure 10 below). The simple design and use of less raw material for biogas generation explain the fixed dome's appeal. Respondents also admit that the lack of movable parts and ease of usage on this digester is the reason for choosing this type of digester thus supporting the conclusions of Valequa et al. (2014). The commonly used digesters in developing countries like Ghana are floating drum and fixed dome even though their initial installation costs are quite high. Financing of the installation of biogas fermenters in the studied territory was done at the expense of non-Governmental organizations and also at the expense of self-financing. The share of non-Governmental organizations' funding was 8%, and self-financing was 92%. Human and financial resources coupled with organizational systems are the main challenges hindering the business operations of NGOs (Bromideh, 2011). Respondents installed biogas digesters between 2010 and 2021. It was the most installed in 2018, accounting for 55% (36 out of 65: see Figure 9).

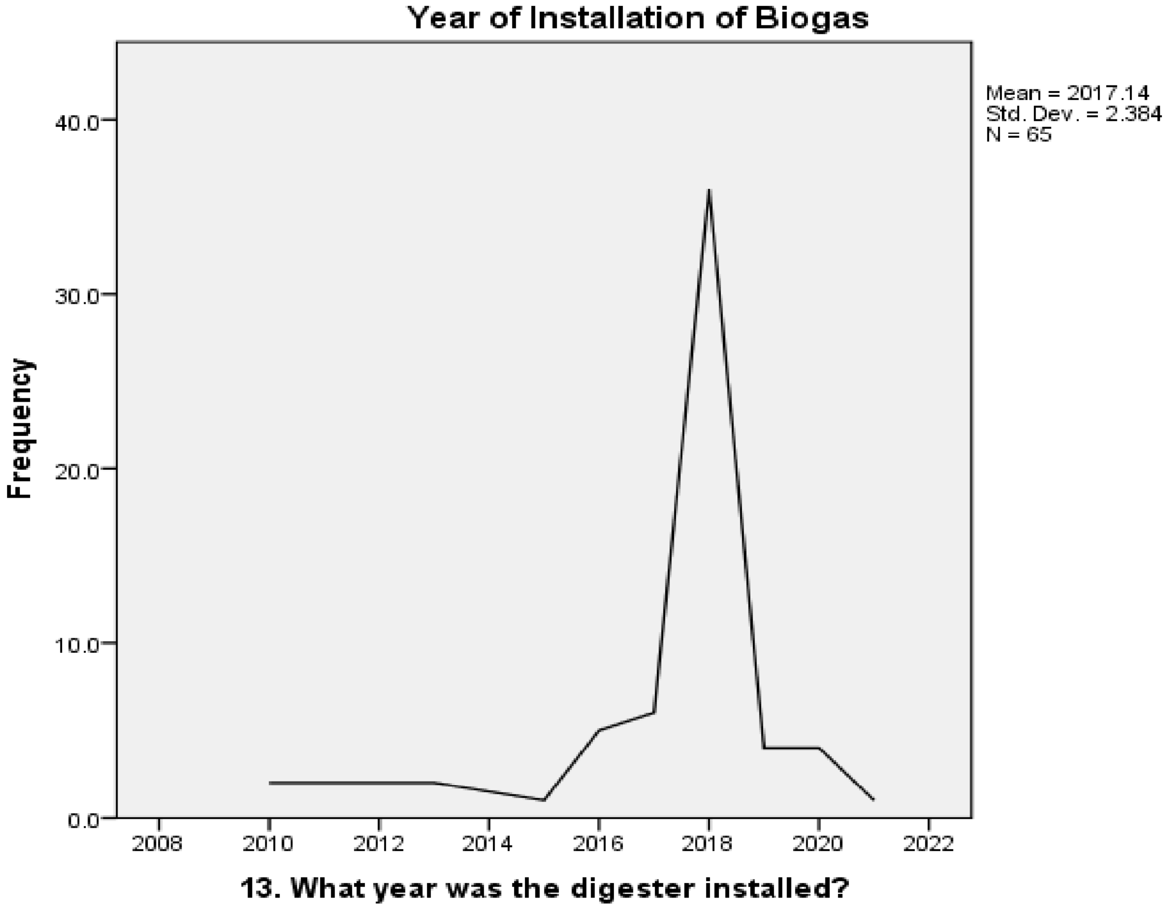

Figure 9: Year of installation of Biogas plant

Most biogas plants were self-financed, although only 48% (31 out of 65) of respondents understood the precise installation costs. Most responders estimated and guessed the cost of supplying biogas plants. The findings reveal that, while the number of individuals embracing biogas technology is minimal, people are making every effort to do so. Despite this, NGOs also do not seem to have paid particular attention to promoting the introduction and use of domestic biogas, probably due to the lack of funds for these NGOs. The government has made little or no effort to encourage the adoption and use of biogas technology. The following comments are from environmental officials in one of the study areas, who acknowledge the government's laxity in this area.

"To be very honest very little has been done in the way of promoting biogas technology in the district and I am not aware of any NGO that is working to promote the use of biogas technology. Some few individual citizens have adopted the technology on their own accord". (Environmental Officer, Effutu Municipality).

Studies on biogas in Uganda and Zimbabwe by Walekwa et al., s (2014) and Marambanyika et al., (2020) sought to identify sources of financial support for pilot plant development and encourage biogas use. They emphasized the importance of the work of non-governmental organizations (NGOs). The research showed that the situation was not the same in the study area. It should be noted that lack of adequate financing was seen as the major hindrance to the adoption and use of biogas technology amongst the families in the two study areas.

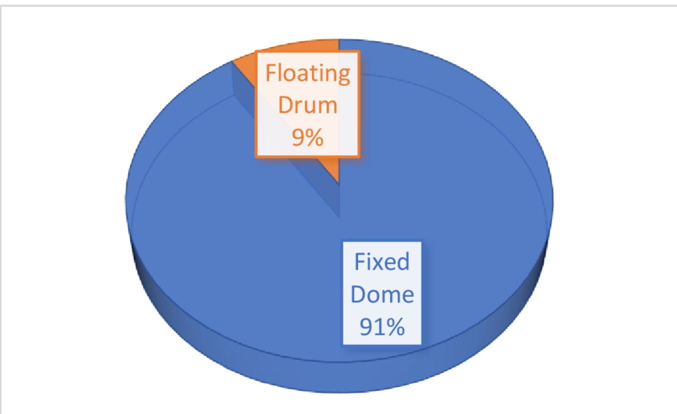

Figure 10: Type of Biogas Installed

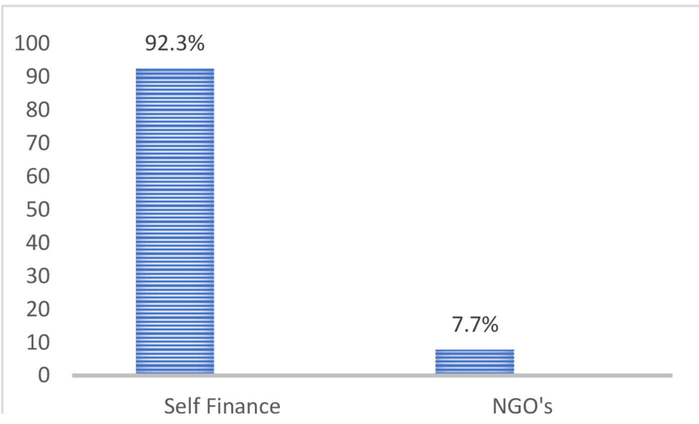

Figure 11: Types of Biogases Installed

4.4 Biogas Appliances, Energy Usage, and Other Energy Sources

Primarily, this study seeks to establish whether families use biogas technology in comparison to other energy sources, and what implications this has on the local economy, quality of life, environment, and climate. Many families utilize one of three sources of fuel: LPG, coal, or wood (Karakara et al., 2021). For this purpose, data was collected on various biogas plants, energy consumption and alternative energy sources for people who do not use biogas. Biogas equipment has been made since the inception of biogas technology.

This section describes and analyzes the information gathered from respondents in two research areas. Figure 12 shows the results of some biogas plants used in homes. Fewer refrigerators (5%; 3 out of 65 responses) and more biogas stoves (36.9%; 24 out of 65 responses) were adopted. Because of their exorbitant cost, biogas refrigerators are considered a luxury item. Tumwesige et al. (2014) confirms this finding. The use of biogas lamps has gained popularity over the period yet still biogas stoves remain the most popular and widely used. The bulk of the biogas energy consumed in the research area (97%, or 63 out of 65 households) is used for cooking, according to the statistics. Lighting was the next common use for the gas produced, making up 23% of the collated data. Due to the close interaction between the two types of biogas appliances, biogas ovens and cookers have been the most used appliances. (See Figure 12). 15 out of the 65 households, or 23%, use biogas lighting, which involves using plants to illuminate their houses. According to Pathak et al. (2009) and Surendra et al. (2014), 80% of biogas is used as a substitute for firewood, while the remaining 20% is used for cooking and domestic lighting as an alternative to paraffin. The findings in this study confirm their conclusions.

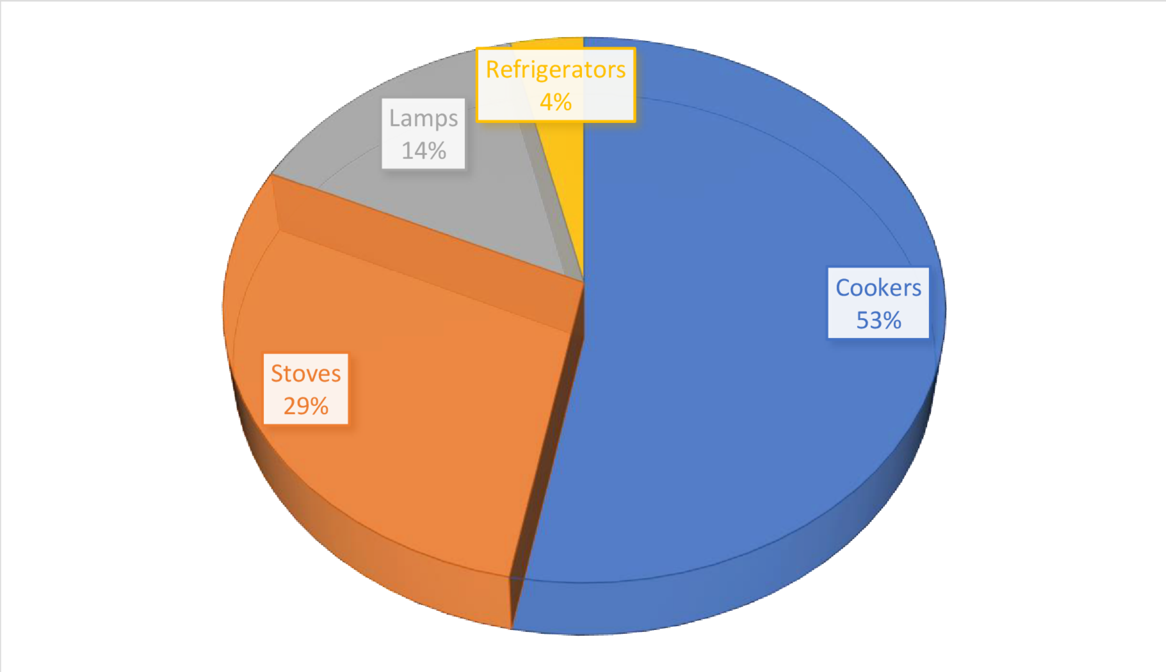

Figure 12: Type of Biogas Appliances used.

The collated results from the study area shows that only 21 percent of respondents had adopted and used biogas technology whereas 79 percent did not. This finding is consistent with arguments by (Mwirigi et al., 2014) which states that In Sub-Saharan Africa (SSA), a high proportion of the population rely on traditional biomass for domestic energy. Respondents without biogas technology reported using alternative energy sources for lighting and cooking. The information obtained through interviews and careful observations showed that the research area depended on two types of energy: biomass and hydroelectric energy. Ghana since efforts made by government to reduce households' reliance on firewood and charcoal has not achieved a lot.(Kwakwa et al. 2013) Households that had biogas plants installed admitted to using it primarily for cooking as indicated in figure 13.

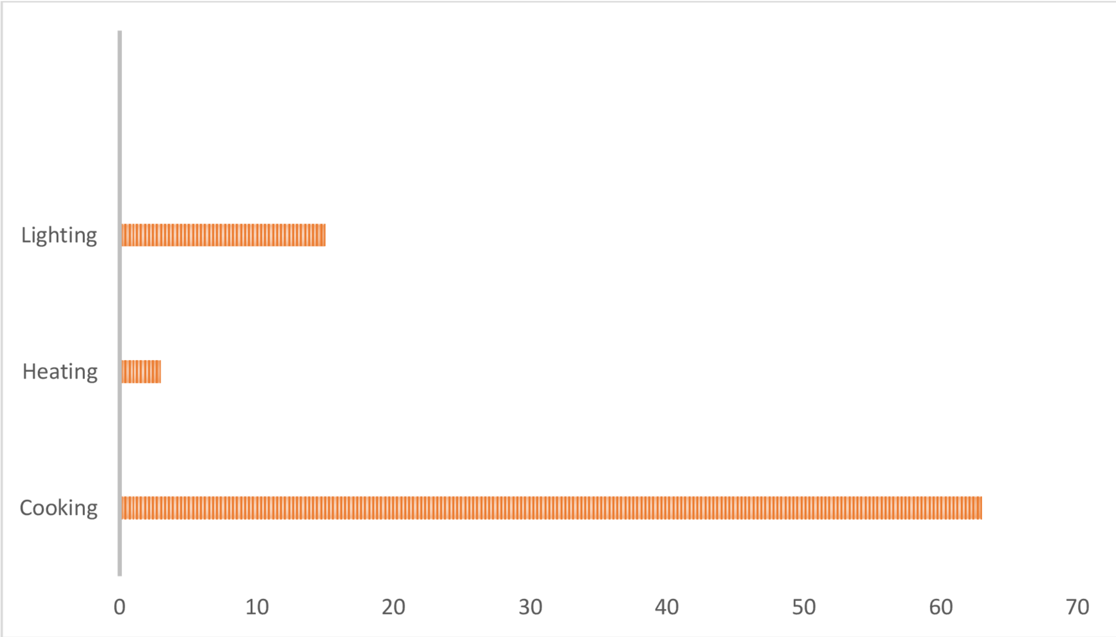

Figure 13: Purpose of biogas plants

Many Ghanaian homes rely on hydroelectric electricity (often from the Akosombo Dam) for lighting and other purposes. Wood fuel and/or charcoal are frequently used in cooking because they are abundantly available in the region and are less expensive, easier to use than other energy sources, and provide an alternate source of energy for cooking. This information supports the claim by (Sola et al., 2017) that in Sub-Saharan Africa (SSA), the production and use of wood fuel remains an important socio-economic activity with more than 70% of the population relying on wood fuel as their primary household energy source. The use of renewable energy resources are inhibited by factors such as expensive installation and maintenance costs for solar and hydropower, poor performance, and a plentiful supply of firewood.

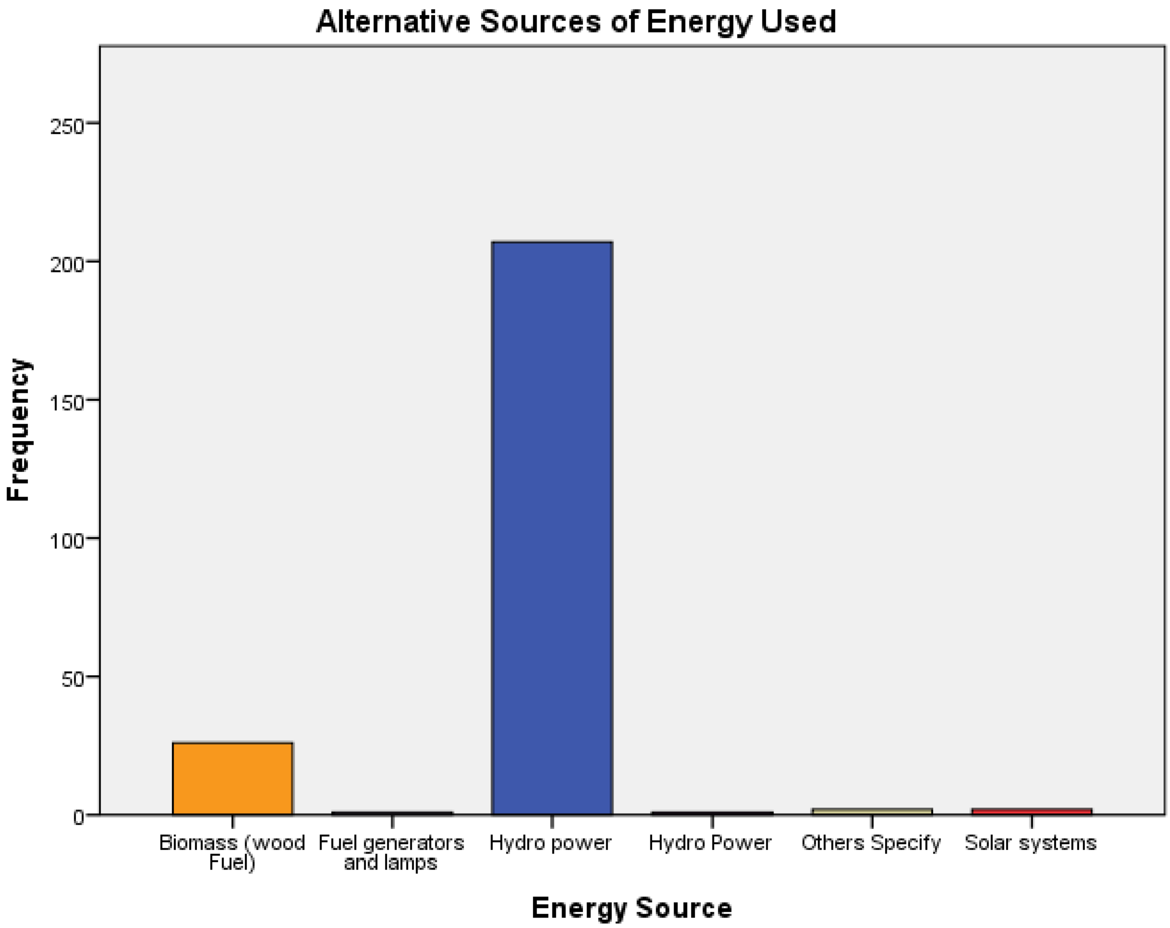

Figure 14: Alternative sources of energy adopted by households.

4.5 Feedstock and Agriculture Activity Engaged in by Households

This part of the study will not only focus on the amount of organic waste available but also on agricultural raw materials and biomass to provide state-of-the-art energy available affordable, reliable, and sustainable in both research areas. Examine household activity records. Find out how it can be used.

4.5.1 Feedstock

Data on the types of raw materials usually utilized in biogas production, including animal, human, and home waste, were obtained from respondents who had established biogas plants. A better way to comprehend the many sorts of garbage produced and consumed at home, particularly in the study region's biogas-producing capabilities.

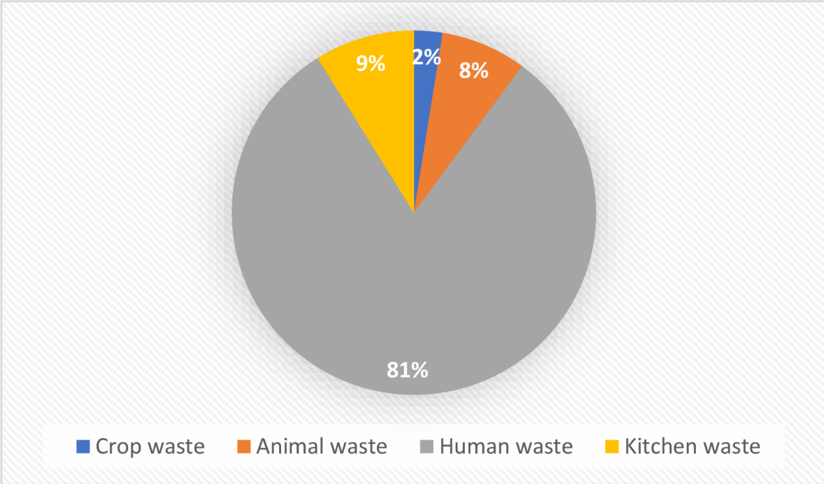

Figure 11: Type of feedstock used for biogas plan.

As shown in Figure 15, biogas plants can use a variety of feedstocks. According to the data from the field, the sixty-five biogas households' users used four types of raw materials. 81% of the total waste used was human waste while 9% was kitchen waste and 8% and 3% animal and crop wastes respectively. Kitchen organic waste is one of the least used raw materials. Human toilets are widely used because they are available in bulk and very cheap as most rescuers have access to toilets. The utilization of human waste for biogas generation offers several environmental and alternative energy benefits. 2015 (Andriani et al.) Some households generate significant amounts of waste, with biogas plants using 9% of kitchen waste as feedstock. According to (Andriani et al., 2015) The use of human excreta for biogas generation considered beneficial either in terms of process or environment. Figure 15 offers more specific information about the use of raw resources. On a (Likert) scale of 1 to 4, with 1 denoting "simple to prepare, 2 equals easy to obtain, 3 equals affordable, and 4 equals expensive, respondents' responses were scored. According to the survey results, 60% of respondents said the ingredient was cheap, 35% said it was easily available, and 5% said it was easier to prepare in the region. The finding can be related to the economic activities, household composition, and to some level the occupation of respondents in the study area.

4.5.2 Agricultural Activities Engaged in By Households

Across the two study regions, 84 out of the 303 households representing 28% carried out various agricultural activities including fishing. Others were hired to work as laborers on lands belonging to others, while others work on their lands. Many respondents (40 out of 84) were employed in agriculture, of which 32 were employed in mixed farming, 10 reared only poultry and 13 reared livestock. Figure 16 shows the distribution of the percentage of connections between households.

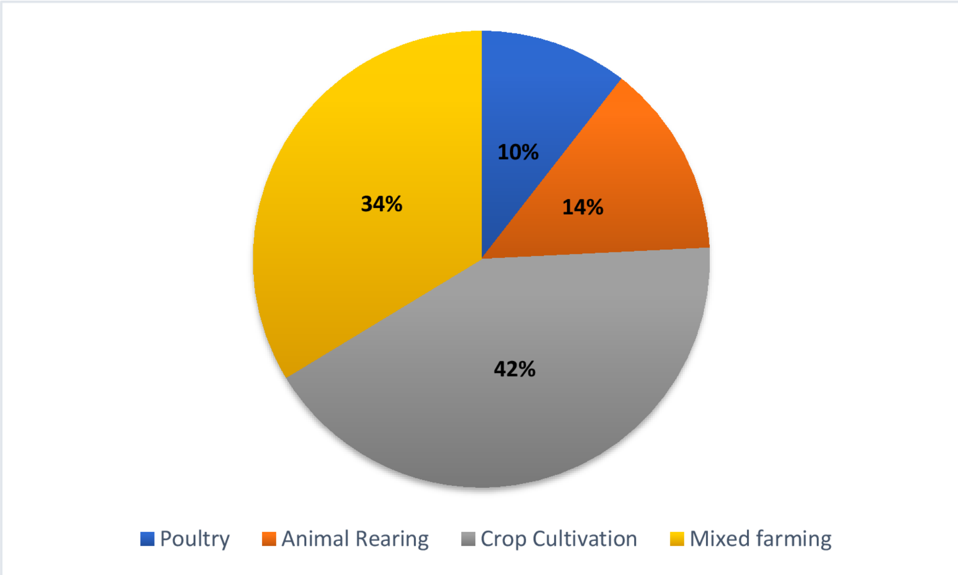

Figure 12: Agriculture Activities carried out by Households.

4.6 Perception of households on biogas plants versus wood fuel

This sub section investigates how people view the use of biogas in comparison to other forms of energy. This section also goes through the elements that have affected the adoption of biogas in households. Determine the socioeconomic, health, environmental, and climate implications of household usage of biogas technology rather than firewood. Figure 17 depicts household attitudes about the usage of biogas for home purposes. Of the 303 households surveyed, 41% admitted to the clean and smoke free nature of biogas energy. Respondents that partook in this research agreed strongly that biogas was easy to use and agreed that using biogas technology gives women and children time to engage in productive activities and education too. Some respondents also agreed that it was affordable in the long run.

Data presented in Figure 17 shows that households in the study area receive little or no government subsidies/support which impacts their decision to adopt and use biogas technology. This finding demonstrates that biogas consumers are fully aware of the importance of biogas as a source of clean and environmentally friendly energy. Chelagat (2016) came to the same conclusion after his research revealed that when trash (raw material) is widely accessible, the adoption and usage of biogas deliver clean energy at affordable costs. Conclusions that can be drawn from these observations are that most respondents are fully aware of the benefits of adopting and using biogas technology and consider biogas as an environmentally friendly energy source.

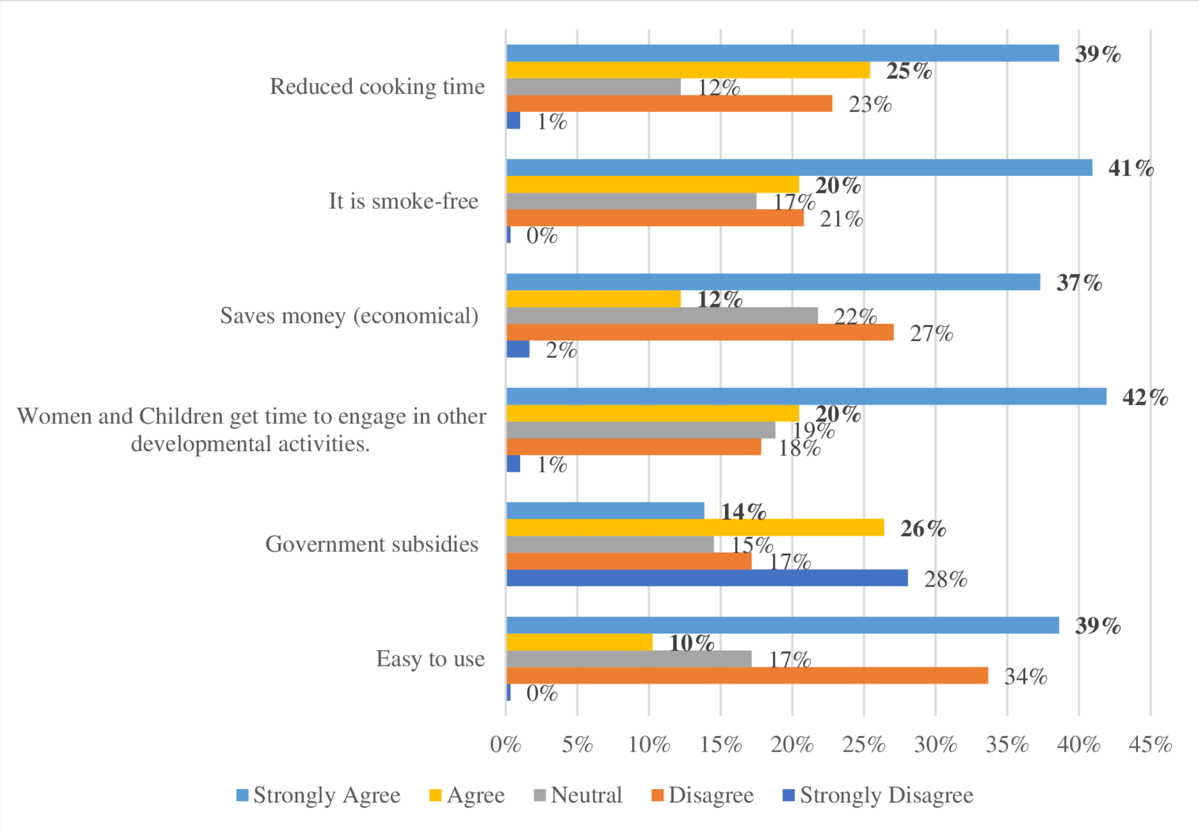

Figure 13: Household Perception on the adoption of biogas

4.6.1 Factors Motivating Biogas Adoption.

Considering respondents perceptions on adopting and using biogas, contributors were given variables as to why they were encouraged to adopt and use biogas technology sustainably. There is a link between the motivations for adopting and the kind of biogas chosen by families. The mean, standard deviation, and variance of the stimulus components are shown in Table 8. According to the information acquired, using biogas saves cooking time (see results in table 8). This is a significant incentive for families to install biogas systems. Furthermore, "women and children with time to participate in constructive education and activities" (average = 3.83) are

a crucial factor that can drive biogas adoption and usage. The respondents found biogas as a promoter to supply of energy as the least motivating factor. Table 8 shows that respondents do not understand the benefits due to a knowledge gap. This is due to the difficulty in obtaining biogas information.

Table 8: Descriptive Statistics on factors that lead to biogas adoption.

	Mean		Std. Deviation	Variance
	Statistic	Std. Error	Statistic	Statistic
Reduces firewood collection time.	3.44	.081	1.408	1.984
It takes less time to cook.	4.05	.057	.999	.998
Children and women have far more time to devote to education and other positive activities.	3.83	.068	1.178	1.388
Provide employment opportunities	3.63	.074	1.291	1.666
Household savings and wages have increased.	3.80	.066	1.144	1.309
The cost of rubbish collection is reduced.	3.74	.071	1.237	1.531
Promotes the generation of energy	3.89	.121	2.114	4.471
Using bio slurry derived from biogas increases crop yields.	3.72	.071	1.235	1.526

Cooking was the main activity using the homemade biogas plant, as shown in the biogas consumption results in Table 13. In fact, this shows the appliances that use the energy from the biogas plant (biogas cookers: 53%). Obviously, most women prepare meals at home. With the high number of respondents being men implies that women are gender sensitive, particularly when providing unpaid care such as cooking and caring for the house. Moreover, the impacts of this study could lead to large-scale legislative initiatives promoting the adoption and use of biogas technology, which could significantly improve the health and well-being of women in the area. Women will profit from home biogas adoption since they will have less time to gather fuel and more time to dedicate to production activities, while their household expenditures will rise owing to increased energy supply. The increased income and savings were emphasized as an additional factor aiding the fulfilment of the Sustainable Development Goals (SDGs).

4.6.2 Multivariate Analysis of Variance Test Results

The objective of this study was to analyze the impacts of the adoption of biogas technology in households. It was done using a multi-variate analysis of variance test. The test was performed on a dependent variable, which is the likelihood that a home will be fitted with a biogas system. It considered various factors such as the environment, socioeconomic status, and health. Families rated these factors on a scale of 1 to 5. The minimum and maximum values are one and five. Each chapter includes three measures of human health and environmental consequences, as well as eight indications of social and economic advantages.

4.6.3 Socio-Economic Valuation

The outcomes of the parallel box test carried out with SPSS are displayed in Table 9. An alpha value of 0.5 was used to assess the outcomes of the descriptive analysis. Statistically speaking, the M-box value of 571.015 is not significant (Sig = 0.000). The covariance matrix indicates that the adoption and utilization of residential biogas technology will significantly affect the objectives of sustainable development goals.

Table 9: Box's Test of Equality of Covariance Matrices[a]

Box's M	571.015
F	15.094
df1	36
df2	44724.615
Sig.	0.000

Table 10 displays the Levine test findings for socioeconomic advantages with equal error variances. MANOVA and ANOVA are evaluated using Levene's test. This presupposes that the variance in the groups analyzed is the same. (Sig =.065,.007,.003,.005, and 857.) Three of these values (0.065, 0.949, and 0.857) appear to be substantially more than the alpha of 0.05. (For example, gathering firewood, producing jobs, and composting produced from biogas).

Variance measurements for dependent variables are standardized. and have been proven not to contradict the variables' discussion. According to the analysis performed on the collected data, the adoption and implementation of biogas technology in homes lowers sums of monies expended on waste discarding, boosts domestic incomes, and brings women with more potentials and time to take part in educational and job activities that women and children can benefit from. Operating biogas technological innovation has tremendous social and monetary perks for owners, as reports have revealed and determine.

Table 10: Levene's Test of Equality of Error Variances[a]

	F	dfl	df2	Sig.
In general, the time required to obtain firewood has decreased.	3.421	1	297	.065
The amount of time spent cooking is maintained to a bare minimum.	4.040	1	297	.045
Children and women now have more time to learn and participate in useful activities.	6.165	1	297	.014
Job generation	.004	1	297	.949
Improves a family's ability to earn and save more money.	7.452	1	297	.007
The cost of waste collection is kept to a minimum.	9.227	1	297	.003
Increases the supply of energy.	7.826	1	297	.005
Using bio slurry generated by biogas boosts crop yields.	.033	1	297	.857

The findings of the multivariate test, as well as the impact of biogas on families and the accompanying social and economic advantages, are shown in Table 11. In this investigation, Wilk, s Lambda test was utilized due to its resilience in dealing with huge samples. Important for discovering intrinsic differences between sets of dependent variables that are linearly arranged. The influence of the group of independent factors is important because it reveals.

the degree of variation in the size of the dependent variables provided in the socioeconomic advantages of biogas usage, which are still reliant on the same alpha 05 thresholds as formerly. A score of 0.003 is given for biogas adoption and use to indicate that respondents do not believe that biogas adoption and use has a significant impact on their family's socioeconomic income. The data show that 8 independent variables significantly affected whether biogas was more economically advantageous than fuel in reaching the SDGs. Furthermore, it is abundantly obvious that biogas is essential for reaching development goals due to variable like “saving families time and giving women and children enough time to engage in education and other beneficial pursuits.

Table 11: Multivariate Test effect of the presence of biogas Socio-Economic benefits

Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.948	655.602[a]	8.000	290.000	.000	.948	5244.813	1.000
	Wilks' Lambda	.052	655.602[a]	8.000	290.000	.000	.948	5244.813	1.000
	Hotelling's Trace	18.086	655.602[a]	8.000	290.000	.000	.948	5244.813	1.000
	Roy's Largest Root	18.086	655.602[a]	8.000	290.000	.000	.948	5244.813	1.000
Is there a biogas digester in your home?	Pillai's Trace	.077	3.042[a]	8.000	290.000	.003	.077	24.337	.959
	Wilks' Lambda	.923	3.042[a]	8.000	290.000	.003	.077	24.337	.959
	Hotelling's Trace	.084	3.042[a]	8.000	290.000	.003	.077	24.337	.959
	Roy's Largest Root	.084	3.042[a]	8.000	290.000	.003	.077	24.337	.959

4.6.4 Health Assessment

Life expectancy, ophthalmic, and health evaluations included respiratory complications inflicted on by the removal of harmful gases and waste. In table 12, there is a presentation of the results of the covariance equality box test which was adopted to test for robustness. The outcomes gave a strong indication of a significant difference between the covariance matrices of the dependent variables, which goes against the principle of homogeneity because it implies that the covariance matrices are not equal. The findings of this study demonstrate the unequal distribution of the study population as well as the effects of biogas acceptance and use on sanitation, waste management, eye and lung risks, and geriatric health.

Table 12: Box's Test of Equality of Covariance Matrices[a]

Box's Box's M	3.511
F	.575
df1	6
df2	81796.525
Sig.	.751

Table 13: Levene's Test of Equality of Error Variances[a]

	F	**df1**	**df2**	**Sig.**
Prolonged life expectancy	1.685	1	301	.195
Minimize diseases caused by irritating smoke in the lungs and eyes.	.011	1	301	.917
It is to get rid of trash and sewage.	.304	1	301	.582

The results of the variance test are shown in the table below. The test yielded positive results when the independent and dependent variable quantity were analyzed. Detected consequences imply that the notions for group variations are correct, signaling that the independent variable quantity is not significant statistically. Sig vs alpha (a = 0.05). = (0.195,0.917,.582) are all greater.

Table 14: The Multivariate Test effect of the presence of biogas in a household On Health

Multivariate Tests[c]

Effect		Value	*F*	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.901	906.460[a]	3.000	299.000	.000	.901	2719.381	1.000
	Wilks' Lambda	.099	906.460[a]	3.000	299.000	.000	.901	2719.381	1.000
	Hotelling's Trace	9.095	906.460[a]	3.000	299.000	.000	.901	2719.381	1.000
	Roy's Largest Root	9.095	906.460[a]	3.000	299.000	.000	.901	2719.381	1.000
Do you have any biogas digester installed?	Pillai's Trace	.002	.223[a]	3.000	299.000	.880	.002	.670	.092
	Wilks' Lambda	.998	.223[a]	3.000	299.000	.880	.002	.670	.092
	Hotelling's Trace	.002	.223[a]	3.000	299.000	.880	.002	.670	.092
	Roy's Largest Root	.002	.223[a]	3.000	299.000	.880	.002	.670	.092

Table 14 depicts the impact of independent variables (is a biogas plant installed?) on population health throughout the introduction and use of biogas energy, based on the three components of the study. The significance value (Sig.) is 880, which is bigger than alpha. None of the examinations appear to have noteworthy results, according to the findings. If the null hypothesis is discovered to be accurate, it signals that the dependent variables are not unique among groups. As a result, shifting away from traditional fuels (LPG, wood, etc.) and toward biogas has a huge influence on supporting healthier lifestyles. According to a GTZ study released in 2018, biogas acceptability and use are at the core of individuals, societies, and the healthcare sector. According to the findings of the study, biogas-powered dwellings have a longer lifespan and might be employed as a long-term waste disposal method. Adopting and utilizing biogas technology supports the adage by enhancing savings, productivity, and long-term well-being. Without a question, health is wealth.

4.6.5 Environmental Assessment

To evaluate the effects of biogas, an environmental impact analysis was also carried out. Descriptive statistics for multivariate and Levine's test using SPSS are provided in Tables 15, 16 and 17. The data required to compute the overall impact (reduction of deforestation, air pollution, and CO2 emissions) on the profitability of the biogas business is contained in each dependent variable. The standard deviations are 1,313, 1,155, and 1,210, while the averages are 3.63, 3.91, and 3.79, respectively. Tables 15, 16, and 17 indicate that the three independent variables are all statistically significant, with just a little interdependency. Nonetheless, the considerations involved highlighting the importance of user acceptability of biogas technology in bringing about positive environmental changes and supporting SDG accomplishment. As a result, the consumption and utilization of biogas are viewed as a long-term answer to achieving the company's long-term goals.

Table 15: Descriptive Statistics on Environmental Assessment

	Do you have any biogas digester installed?	Mean	Std. Deviation	N
Deforestation is declining.	No	3.62	1.312	238
	Yes	3.68	1.324	65
	Total	3.63	1.313	303
Reduction of air pollution	No	3.91	1.158	238
	Yes	3.92	1.150	65
	Total	3.91	1.155	303
lowering carbon emissions in the domestic setting	No	3.80	1.204	238
	Yes	3.74	1.241	65
	Total	3.79	1.210	303

Each result from the Levene's test for equal variance is more than or equal to alpha (0.5), and the reported Sig values of 0.984, 0.767, and 0.478 are all within the permissible range for a fair distribution of household biogas plants. But it has a beneficial effect on global warming because it reduces CO2 emitted into the atmosphere as Paolini (2018) argues. The experimental results show that the use and consumption of biogas is considered an ecological and sustainable strategy to achieve the SDGs important for research.

Table 16: Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Deforestation is minimized.	.000	1	301	.984
Controls pollutants in the air	.088	1	301	.767
Reduces the amount of carbon emitted in the home.	.505	1	301	.478

Multivariate test results illustrating the efficiency and environmental benefits of residential biogas are presented in the table below. The null hypothesis is still valid in this situation because the table's sign. =.778 is higher than alpha (a =.05). This gives a strong indication that that adopting and using biogas provides a great opportunity to achieve sustainable development Goals (SDGs) The social acceptance of biogas is often hampered by environmental and health concerns.(Paolini et al., 2018). Biogas is being falsely marketed as a renewable energy solution to solve the problems of an already polluting industry, Concentrated Animal Feeding Operations ("CAFOs").(Gittelson et al., 2021). Conclusions drawn from this this work can be used as a yardstick on how to address the issues. The conclusions attained in this research study can be implemented as a benchmark for how to handle the difficulty with discharges as well as other connected ecological obstacles.

Table 17: Multivariate Test effect on biogas regarding Environmental Benefits

Multivariate Tests[c]

Effect		Value	*F*	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.901	910.780[a]	3.000	299.000	.000	.901	2732.341	1.000
	Wilks' Lambda	.099	910.780[a]	3.000	299.000	.000	.901	2732.341	1.000
	Hotelling's Trace	9.138	910.780[a]	3.000	299.000	.000	.901	2732.341	1.000
	Roy's Largest Root	9.138	910.780[a]	3.000	299.000	.000	.901	2732.341	1.000
Do you have any biogas digester installed?	Pillai's Trace	.004	.365[a]	3.000	299.000	.778	.004	1.095	.122
	Wilks' Lambda	.996	.365[a]	3.000	299.000	.778	.004	1.095	.122
	Hotelling's Trace	.004	.365[a]	3.000	299.000	.778	.004	1.095	.122
	Roy's Largest Root	.004	.365[a]	3.000	299.000	.778	.004	1.095	.122

5.0 SUMMARY OF FINDINGS RECOMMENDATION AND CONCLUSIONS

5.1 Summary of Key Findings

It was shown that the major source of revenue for households is from business activities. The easiest feedstock for the generation of biogas is human feces. 13.5 percent of households in the study region engage in domestic and business agriculture, a very uncommon situation. Since farm waste is in fact only supplied in lesser volumes, there is a substantial trust on human waste as a feedstock for biogas making. The most common biogas-powered appliances are ovens and stoves, both of which are used for cooking. Hydropower and wood fuel are the primary energy sources for families without biogas facilities.

Out of the respondents chosen at random for this study, 65 have biogas plants installed, making up 21% of the total polled, while the remaining 79% do not, indicating a limited potential for biogas in the study area. However, according to municipal experts, with the assistance of non-governmental organizations and significant government effort, the usage of biogas may be enhanced. These services might include community and family services funding, capacity building, and public education. Families that adopt and use biogas technology get various benefits, the most important of which are lower greenhouse gas emissions, faster cooking times, clean and smoke-free energy sources, and lower long-term costs. The resultant product being bio-slurry can serve as a good source nutrient for crop production.

5.2 Recommendations and Conclusion

Data from both households and the city council show that biogas is not widely used in the study areas, even though many people are aware of its benefits. Biogas technologies for domestic use are not novel. This means that a lot of work has been done in the last few years. Fermentation technologies have also been improved, as have cost savings. Furthermore, a large amount of information has been gathered so that current project leaders have accurate data and a thorough understanding of the issues, particularly when it comes to technical aspects and "Best Practices" for these types of projects. The low availability of biogas can be attributed to several factors and is a barrier to its widespread adoption. Biogas has numerous socioeconomic, environmental, and health advantages. As a result, it is very prudent to provide recommendations on how to overcome the challenges to increase attendance and adoption.

The adoption of biogas is hampered by a lack of access to biogas knowledge and technical skills, a costly initial investment, the availability of wood fuel, and a lack of government support. Based on this, the Ghanaian government is advised to make a determined effort to properly analyze the creation and implementation of renewable energy policies and strategies, notably biogas. Importantly, local governments responsible for environmental sustainability should be able to give technical knowledge to families on renewable energy sources as long-term home fuel sources.

Again, the Ghanaian government must implement subsidies to encourage the use of biogas. According to environmental officials in the study areas, LPG is very expensive today, and many people complain about it; coal is inexpensive but has a negative impact on the environment; and firewood is not recommended due to its obvious environmental and climatic impact. However, few private companies approach local assemblies with plans to promote this technology, but these plans do not materialize due to a lack of support from the central government and finances.

In Ghana, there is currently no political incentive to promote biogas technology. As a result, the government must prioritize the introduction of biogas through effective policies that create an enabling environment for NGOs and private companies to implement. This contributes to the achievement of the global goals (SDGs) for environmental protection and sustainability. Governments and project promoters are encouraged not to start from scratch, but rather to leverage potential synergies between different types of actors at each stage of development: local incentive frameworks, funding, capacity building, and technical design.

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