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Influencing Factors for Household Decisions on Adoption and Use of Biogas Technology: Case of Ghana

MASTER'S THESIS

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DECLARATION

I, Konadu Peter Kwame, hereby declare that I have done this thesis entitled “influencing factors for household decisions on adoption and use of biogas technology: case of Ghana” independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 20.4.2023

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Konadu Peter Kwame

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ABSTRACT

Investments in renewable energy technology are required because the majority African nations experience energy insecurity. According to a 2011 report by the United Nations, everyone needs access to sustainable energy, especially in emerging countries, to meet the country's growing energy needs and mitigate the effects of climate change. The main objective of the current study was to investigate the factors that influence household decisions about the adoption and use of biogas technologies and the benefits of implementation in terms of socio-economic, environmental, health, and climate issues in relation among households in rural areas of the Offinso North district in the Ashanti region of Ghana. The research design for the current study was quantitative with surveys using questionnaires to obtain the opinions of the respondents to formulate the research findings. To achieve the objective of this study, explanatory and descriptive research methods were employed. The research focused on rural households in the Offinso North (Ashanti region) in Ghana, and stakeholders in government and non-government institutions. The sample size was determined based on the number of adopters of the household and who were willing to respond to the questionnaire in the Offinso North District. Convenient sampling technique was employed. It was found that household adopters strongly agreed that the price of biogas technology installation is greater, training related to biogas technology is difficult to access, and the advantages of biogas energy are not widely known. The findings also showed that the family is reluctant to use biogas technology, the ability to obtain credit is challenging, and the time saved by biogas can be used for other tasks that generate cash. Furthermore, having a reliable and sufficient water source is challenging, water supplies are insufficient and unreliable, crop yields are directly increased by biogas, and there are few livestock. It was also found that political backing and targeted initiatives to advance biogas technologies are lacking, there is lack of knowledge and minimal communication with potential adopters, there is lack of understanding among the populace as a whole, there is lack of consumer interest and public participation, adoption of biogas technologies is hampered by low literacy rates, adoption is still going slowly, lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas, installations of biogas entail significant financial outlays, there are not enough resources, and there is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized. Lastly, it was found that for the best biogas production, household adopters must use feedstocks with the right C/N ratio, Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove, and to make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook are some approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure.

Key words: household decisions; adoption and use of biogas technologies; socio-economic issues; environmental issues; health issues; and climate issues.

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ABBREVIATIONS USED IN THE THESIS

Millennium Development Goals (MDGs)

Sustainable Development Goals (SDGs)

Department of Energy (DoE)

South African Biogas Industry Association (SABIA)

Ministry of Energy (MoE)

Institute of Industrial Research (IIR)

German Agency for Technical Cooperation (GTZ)

anaerobic baffled reactors (ABR)

upflow anaerobic sludge blankets (UASB)

Lavender Hill fecal treatment plant (LHFTP)

Mudor waste water plant (MWWP)

European Union (EU)

Asia-Pacific Countries (APAC)

National Project on Biogas Development (NPBD)

National Biogas and Manure Management Programme (NBMMP)

Biogas Support Programme (BSP)

palm oil mill effluent (POME)

sewage treatment plants (STP)

municipal solid waste (MSW)

Ministry of Agriculture, Forestry, and Fisheries (MAFF)

Cambodia Climate Change Alliance (CCCA)

National Biodigester Programme (NBP)

local investment programmes (LIP)

climate investment programmes (KLIMP)

Voluntary Emission Reduction (VER)

research and development (R&D)

renewable energy technologies (RETs)

biogas generation technology (BGT)

Khyber Pakhtunkhwa province (KPK)

crucial influencing factors (CRIFs)

propensity score matching (PSM)

statistical package for social sciences (SPSS)

Centre for Innovation and Research in Teaching (CIRT)

1. INTRODUCTION

Investments in renewable energy technology are required because the majority of African nations experience energy insecurity (Aliyu, Modu, and Tan 2017). The oil that the majority of African nations import from foreign nations inhibits economic progress and emphasizes how closely tied food security and energy security are to one another. Without enough energy, achieving food security is nearly impossible as food production and delivery require energy (Rasul and Sharma 2016). In light of the aforementioned circumstance, experts such as Maxwell (2014) have proposed that the implementation of biogas technology can be a viable strategy for lowering local levels of energy insecurity. Biogas digesters, according to Smith, Goebel and Blignaut (2014), helped achieve the Millennium Development Goals (MDGs) and will undoubtedly be essential to achieve the ensuing Sustainable Development Goals (SDGs). Furthermore, it is expected that this will promote socioeconomic development, open up job opportunities, and lead to a sustainable and environmentally friendly growth route (Department of Energy-DoE 2015; South African Biogas Industry Association-SABIA 2016).

Rural populations spend money on electricity, but prices are still skyrocketing; Eskom estimates that expenses have increased by up to six times since 2006 (DoE 2012; Mwirigi et al. 2014; Puzzolo et al. 2016; Shallo, Ayele and Sime 2020; Ting and Byrne 2020). The Department of Energy (2012) added that this increase in energy prices would put a lot of pressure on rural populations. This forecast quickly came true as the load-shedding and outages took over in a few short years and are still going strong today. It is crucial that the government take into account potential energy replacements in response to the crisis and high energy prices (Arthur, Baidoo and Antwi 2011). The adoption of biogas is a critical step in addressing energy shortages. Furthermore, because it is deemed useful for most rural populations, biogas energy is one of the most suitable energy resources to tackle this difficulty (see Msibi and Kornelius 2017). But because this energy is derived from garbage, there are unique difficulties. One of them is the offensive fragrance, which some people may find repulsive and may cause them to react or adopt in an unfavourable way.

Technology adoption is a difficult process that can involve adopting new technology or changing an existing technology. Farmers who are more experienced and older tend to be risk-averse (Meijer et al. 2015). According to Sibisi and Green's argument of (2005), perceptions, knowledge, and demographic considerations will all affect the uptake of renewable energy. Additionally, the choice of energy sources is greatly influenced by the economic level, size, and knowledge of the many energy sources available to the household. For example, DoE (2012) found that South African low-income households heavily rely on wood for cooking fuel. Energy is a crucial factor in determining the rate and stage of any nation's growth. For most developing nations, including Ghana, the services and supply of sustainable, affordable, adequate and reliable energy supplies have been a persistent and critical challenge. Energy is essential for both industrialised and developing nations to achieve inclusive and sustained growth, as evidenced by more recent research linking development to increased energy use (Negro et al., 2012).

Energy concerns have a significant impact on human, environmental, and social development in addition to economic progress (Amigun et al., 2011). Access to better energy services is essential for improving the nation's health, reducing poverty, fostering economic growth, boosting competitiveness, and promoting gender equality (Amigun et al., 2008). South Africa, like most other nations, relies heavily on fossil fuels to supply its energy needs. However, due to the ecological and environmental issues related to its uses, this energy source has increasingly become unsustainable (Karekezi, 2002). Due to its heavy dependence on coal, the nation emits 9.1 metric tons of carbon dioxide per person, compared to 0.8 for sub-Saharan Africa and 5.4 for the global average (World Bank, 2015). Concerns about the sustainability of fossil fuels have increased public awareness of the need for and viability of renewable energy sources, which have been highlighted as an alternative solution to these issues (Karekezi, 2002). Evidence from the literature shows that a significant number of countries have used renewable energy sources to close the energy gap (Awan & Khan, 2014; Charters, 2001).

Energy sources that are continuously and freely produced in nature and are not exhaustible since they come from an endless source are known as renewable energy sources (Shahzad, 2012). Today, most of the world's 2.5 billion inhabitants rely on conventional biomass fuel for heating, lighting, and cooking. By 2030, it is estimated that more than 1.4 billion people could be without access to modern energy sources (Ghimire, 2013; Klasen et al., 2013). In addition, in poor nations, 500 million households still use traditional biomass fuel for cooking and heating. These households lack access to modern energy sources (UNDP, 2009; Bazilian et al., 2010). According to Arthur et al. (2011), the widespread depletion of fuelwood inventories would increase demand for the fuel, and the ensuing social and environmental effects force emerging countries to look for alternative and clean fuel sources. Standard of living, health, and ecology would all improve if rural communities stopped using biomass fuel and switched to cleaner technologies. Furthermore, it would increase the likelihood of sustainable economic growth (Bajgain and Shakya, 2005).

Energy poverty refers to the lack of suitable possibilities to access sustainable and ecologically responsible energy resources that could hinder socioeconomic growth in a particular area. Energy poverty is sometimes defined as the inability to use contemporary cooking fuels and the lack of sufficient electrical lights for study or other evening activities with the family (Bridge, 2015). Energy is essential to attempts to reduce poverty and promote sustainable development. Energy has an impact on many aspects of development, including social, economic and environmental factors, as well as livelihoods, water access, agricultural production, population size, health, and gender-related concerns (Elavarasan et al., 2021). The achievement of the Millennium Development Goals (MDGs) depends on everyone having access to affordable, reliable and clean energy, especially in developing countries (Weststrate et al., 2019; Larionova, 2020; Cuenca-Garca et al., 2019). Energy is crucial to achieving universal primary education, according to the UN (2010). Biogas, hydropower, small wind, solar photovoltaics, ethanol and biodiesel, as well as geothermal energy for grid electricity and heat, are examples of renewable energy sources that are currently widely used in some regions and are being introduced in other areas of developing countries (Armin Razmjoo et al., 2020).

Inducing a paradigm shift toward green economies, poverty eradication/reduction, and eventual global sustainable development is largely dependent on renewable energy sources. Authorities pay more attention to solar, wind, geothermal, ocean, and hydro power, as well as other biofuels (biodiesel, ethanol), while placing less of an emphasis on biogas (Tian et al., 2021). However, biogas technology provides many advantages. It is a biological method for handling organic or biodegradable debris that uses anaerobic digestion or processing (biodegradable solid waste, sewage, animal dung, and fecal matter). For many years in Ghana, cowdung has been customary as a fuel source for cooking (Shaibur et al., 2021; Ajieh et al., 2020). This is common in the northern savannah regions, where there is sometimes a shortage of fuel and charcoal for cooking in homes. In Ghana, interest in biogas technology started in the late 1960s, but it was not until the middle of the 1980s that the government gave it the attention it needed (Awafo & Agyeman, 2020). Before the mid-1980s, the government's involvement in the diffusion programmes was mostly centred on providing energy for household cooking (Awafo & Agyeman, 2020).

The need to develop and use alternative sources of cooking fuel was brought into sharp relief by the rapid depletion of the biomass resource base for woodfuels and the predicted increase in demand for woodfuels in the future, along with the associated social and environmental repercussions. Later in the 1987s, the United Nations Children's Fund (UNICEF) helped finance the development of two residential biogas technology plants at Jisonayilli and Kurugu in the northern area (Osei-Marfo et al., 2018). Ghana received a €5 million grant from the German government in 2019 to build a 400kW biogas plant that will generate power (Grant & Oteng-Ababio, 2021). Construction is scheduled to begin on October 1 this year, and the facility must be operational on September 1 next year. Therefore, it is essential to investigate the influencing factors for household decisions on adoption and use of biogas technologies and the implementation benefits in terms of socioeconomic, environmental, health and climate issues in relation between households in the rural areas of Offinso North district in the Ashanti region of Ghana.

1.1 Statement of the Problem

According to a 2011 report by the United Nations, everyone needs access to sustainable energy, especially in emerging nations, to meet the country's burgeoning energy needs and mitigate the effects of climate change. Inducing a paradigm shift toward green economies, poverty eradication/reduction, and eventual global sustainable development is largely dependent on renewable energy sources. The focus of government attention on renewable energy sources is mainly solar, wind, geothermal, oceanic, and hydro power, as well as other biofuels (biodiesel, ethanol), with biogas receiving less attention. However, biogas technology provides many advantages. It is a biological method for handling organic or biodegradable debris that uses anaerobic digestion or processing (biodegradable solid waste, sewage, animal dung, and fecal matter). It happens without oxygen in order to stabilise the organic materials and produce biogas at the same time. Sewage sludge treatment is one of the first applications, say Mata-Alvarez et al. (2014). According to Dahiya & Joseph (2015), biogas technology is typically used for waste management because all other alternatives are either energy intensive, cumbersome, or hazardous to the environment.

Environmentally friendly biogas technology is widely used and has been embraced in many countries. Although its use is progressively increasing in various South American and Asian nations, the same cannot be said about Ghana or Africa as a whole. Residential and commercial biogas technology is widely used in Nepal, China, India, and Latin America (Bensah & Brew-Hamond, 2010; Garfi et al., 2016). Numerous studies have shown that the method offers a number of advantages, such as a sustainable energy source, improved cleanliness, a rich biofertilizer, and lower emissions (Surendra et al. 2014; Rupf et al. 2015; Khann & Martin 2016; Ahiataku-Togobo & Owusu-Obeng 2016). However, the design, construction, and operation of a biogas digester play key roles in the acceptability of biogas technology, according to Sasse (1988), who underlines that biogas technology is only usable when there is a biogas digester or plant. The expense cannot be ignored because building a digester is necessary for biogas technology. According to some experts, digesters' high initial cost is a key barrier to their adoption in Africa, where many people fall below or are below the low-income group level (Karekezi 2002; Amigun & Blottnitz 2010; Bensah & Brew-Hamond 2010; Smith 2011; Mulinda et al. 2013; Rupf et al. 2015).

Biogas technology is conceptually simple and easy to understand and the raw materials are plentiful (Karekezi 2002). However, numerous initiatives have failed or encountered difficulties quickly after their distribution. This can be attributed to the African governments' inability to support the technology through targeted energy policies, sub-par diffusion/dissemination strategies, sub-par digester design and construction, sub-par user operation and maintenance, sub-par project monitoring and follow-up by promoters, and sub-par user ownership responsibility (Njoroge 2002). Only a well-designed biogas digester can meet client/user expectations. Anecdotal data reveal that most digesters are installed or maintained by other professionals who are also service providers rather than biogas technologists, despite the fact that many people from various backgrounds view the biogas sector as lucrative. These service providers (biogas technologists) may or may not have received official training in the construction of biogas digesters from a recognised university or organisation. Numerous other studies have been conducted on the use of biogas technologies in Africa (Lemlem, 2016; Getachew, 2016; Melaku et al., 2017; Woldesilassie and Seyoum, 2017).

Households are less likely to accept technology due to socioeconomic, cultural, institutional, and innovative factors (Kelebe et al., 2017). The quantity of tropical animals, the distance from the market and the distance from the main road are among the elements that have a significant impact on whether or not fuel-efficient stoves will be used (Legesse et al., 2015). The adoption of fuel-efficient stoves is influenced by the financial situation of the household heads (Kanangire et al., 2016). This study suggests that the use of fuel-efficient stoves is positively correlated with household income. Additionally, the emergence of cutting-edge technology, such as fuel-efficient stoves, is greatly influenced by education (Lewis and Pattanayak, 2012; Legesse et al., 2015). The adoption of clean and contemporary energy fuels and technologies by households is influenced by a number of factors, including household size, income, education, and fuel prices (Muller and Yan, 2018). However, the state of energy use today and the variables that influence the adoption of biogas technology in rural households have not been adequately studied. Most rural households still use conventional biomass energy sources and many of them have never heard of the technique.

Furthermore, there has been little progress in biogas installation at the study site; now, only 66 houses are using the technology. Due to the lack of fuelwood and other household energy sources in the research site, it is also very typical to see women and children compete for dung fuel in communal grazing fields. Therefore, it is necessary to investigate why the adoption of biogas technology has been slow. The objective of this study was to investigate the influencing factors for household decisions on adoption and use of biogas technologies and the benefits of implementation in terms of socioeconomic, environmental, health, and climate issues in relation among households in the rural areas of Offinso North district in the Ashanti region of Ghana.

1.2 Significance of the Study

The purpose of the study is to provide policy makers with information on sustainable and flexible methods of influencing factors for home adoption and the advancement of biogas technology. Additionally, it will add to the amount of knowledge already known about biogas technology.

1.3 Organization of the Study

The study was organised into seven sections. The first section focused on the introduction. This was present in the study background, problem statement, significance of the study, and organisation of the study. The second section includes the review of the literature of the study. The third section outlines research objectives, research questions. The fourth section outlines the methods used to carry out the study. This focused on the research design, the study population, the sampling and sampling technique of the study, the data collection tools, the analysis of the data collected, and ethical consideration. The fifth section addressed results and discussion. The sixth section conclusion and the last section presents the references.

2. LITERATURE REVIEW

This section contains history of dissemination of biogas technology in Ghana, review of types of biogas digesters, contribution of biogas production to rural households, challenges facing biogas users in rural communities, factors affecting biogas adoption among rural households, overview and current status of biogas implementation, challenges to biogas implementation in developing countries, strategic measures for improved biogas implementation, and empirical literature.

2.1 History of Dissemination of Biogas Technology in Ghana

Ghana has been a leader in the dissemination of biogas technology since the late 1960s, with the creation of electricity and the production of energy for cooking as the main drivers. According to Bensah and Brew-Hamond (2010) and Ahiataku-Togobo & Owusu-Obeng (2016), most early biogas plants failed soon after project execution due to inadequate distribution procedures and underdeveloped technology (Bensah & Brew-Hamond 2010). The "Integrated Rural Energy and Environmental Project" in Appolonia, Accra, was one of the first significant communal biogas demonstration projects in Ghana, founded by the Ministry of Energy (MoE) in 1986. There, 19 small household digesters were erected. The goal was to supply electricity to light up homes and streets, fuel for cooking and biofertilizer for agriculture (Bensah & Brew-Hamond 2010; Arthur et al. 2011; Bensah et al. 2011), especially for livestock-owning households. 16 digesters were destroyed out of concern for explosion, and three were broken. A 10 m3 digester was built at the Bank of Ghana cow ranch in Shai Hills, Accra, about the same time (Arthur Baidoo & Antwi 2011; Bensah et al. 2011).

2.2 Review of Types of Biogas Digesters

There are three primary types of biogas digesters: balloon, permanent dome, and floating drum (Sasse 1988). Other variants have emerged as a result of adjustments made to meet modern needs. Fixed dome, floating drum, and Puxin digesters are the three main designs that have been developed, tested, and distributed in Ghana (Arthur et al. 2011). The fixed dome is essentially a brick-built underground chamber with a fixed, immovable dome on top for storing gas. They are mostly made because they are considered reasonably priced. The floating drum type consists of an underground digester and a mobile gas holder that has a mild steel drum on top of the digester. In other words, it contains a distinct architecture for producing and gathering gas. The gas storage drums either floats on top of the fermentation slurry or is submerged in its own water jacket (Sasse 1988). Bensah et al. (2011) claim that because the gasholder can be removed at any time to remove scum that has formed, floating drum digesters are perfect for digesting fibrous wastes, such as those from slaughterhouses, particularly the stomach content of cows or goats (inedible offal, lairage washings, sludge, blood, etc.).

However, due to its costly initial investment and ongoing maintenance expenses, the floating drum has become obsolete with the development of the fixed dome digester (Mulinda et al. 2013). The concrete Puxin digester has a carbon fibre gasholder (Bensah et al. 2011). With the exception of the gasholder, it is built by assembling steel shutters for concrete casting of all its components. In addition to the three regularly used biogas systems mentioned above, other biogas systems are used, such as anaerobic baffled reactors (ABR) and upflow anaerobic sludge blankets (UASB). The UASB is a sophisticated system for handling municipal and industrial wastewater. In Korle Gonno, Accra, a new version known as the Lavender Hill fecal treatment plant (LHFTP) and a renovated Mudor waste water plant (MWWP, also UASB), were put into service in November 2016. LHFTP can handle 2.4 million people per day at its maximum capacity of 2,400 m3/d (design capacity: 2,000 m3/d), but MWWP can handle 105,000 people per day at its highest capacity of 21,000 m3/d (design capacity: 18,000 m3/d).

Faecal waste is delivered to the MWWP from a few locations in and around Accra, and the biogas produced there is expected to produce between 400 and 500 kW of power for the national grid. LHFTP collects faeces from both private and public restrooms in Accra, as well as from a few locations outside the city. The ABR is being marketed by IIR for use by homes, businesses, and communities. It resembles a conventional septic tank system. The design, which closely resembles the septic tanks currently in use, was made with the intention of increasing technology acceptance, claim the concept's proponents. But unlike a septic tank, an ABR not only treats wastewater, but also creates gas.

2.3 Contribution of Biogas Production to Rural Households

Msibi and Kornelius (2017) claim that low-income households in Ghana can save costs on fuel wood purchases, as well as the health risks associated with them, by implementing biogas technology. In this sense, people will save money while leading better lives. Importantly, Chakrabarty, Boksh, and Chakraborty (2013) underlined that increased agricultural income is associated with frequent use of biogas digesters in farms. Creating simply electric energy or combining it with carbon credits can accomplish this. Furthermore, rural farming households can benefit greatly from biogas technology. There are 2.3 million farming households in this country and 24% of them still cook with firewood. 33% of people living in the eastern Cape own livestock, with the remaining people farming crops and other types of agriculture. Given that most rural homes use pit toilets, there is a potential for the production of significant amounts of biogas substrate (Statistics South Africa 2016). A significant contribution that biogas can make to low-income rural households is further demonstrated by the fact that up to 14% of the monthly income of rural people is spent on energy purchases, which is believed to be higher than the international standard of 10% for energy power (DoE 2012).

According to Chakrabarty, Boksh, and Chakraborty (2013), biogas generation indirectly increases the income of rural households. This is accomplished by using biogas in place of other energy sources. According to Chakrabarty, Boksh, and Chakraborty (2013), the time saved from gathering and preparing old fuel can also be used to make money. Furthermore, Wargert (2009) asserted that biogas generation could directly influence crop productivity by pointing out that digested slurry is a superior fertiliser. In fact, the substrates after processing produce a significantly superior fertiliser than they did before.

2.4 Challenges Facing Biogas Users in Rural Communities

While low-income rural households can greatly benefit from biogas, there are certain obstacles to its adoption. These difficulties include restrictions on biomass utilisation and unique biogas digester and maintenance requirements. Another issue to consider is water availability, as this puts irrigation water and drinking water in competition (SABIA 2016). However, several studies have investigated the accessibility of grey water (Nape et al. 2019). Furthermore, according to Von Bormann and Gulati (2014), the amount of water required to produce power is expected to increase. Water allocation trade-offs between energy and agriculture will be difficult in this regard.

Although some developing nations, such as China, India, and Nepal, have successfully adopted biogas (see Bond and Templeton 2011), this has not been the case in many other nations where the digesters are not working. This is because there are not enough maintenance resources available, and the facilities that already exist aren't getting fixed. South Africa has also experienced this. For example, SABIA (2016) noted that the energy sector faces serious challenges due to a lack of qualified local labour and skilled manpower, as the system frequently relies on foreign nationals from wealthy countries to run the facilities.

In poor countries, it might be challenging to locate a grid connected to a large-scale biogas programme. Furthermore, the inability of rural farmers to invest in biogas facilities is a barrier to their progress (Wargert 2009). Furthermore, underground methane digesters that are installed are inundated during the rainy season, according to Wargert (2009), which requires a significant amount of maintenance effort and expense. This is related to the construction of methane digesters using unsuitable forms and materials (Mutungwazi, Mukumba and Makaka 2018). According to Taele, Gopinathan, and Mokhutsoane (2007), the seasonal movement of livestock in rural regions makes it challenging to collect enough animal waste to feed biogas digesters and causes a sizable interruption in generation capacity. A large-scale farming system makes it challenging to gather animal faeces, according to Wargert (2009). According to Nape et al. (2019), due to the cold winter months, the methane digesters built in rural communities do not produce enough biogas.

2.5 Factors Affecting Biogas Adoption among Rural Households

According to the literature, a variety of factors can potentially affect the adoption of biogas digesters by rural families. Energy is essential for alleviating poverty, boosting human wellbeing, and raising standards of living, claim Vera and Langlois (2007). However, most of the current energy supply and usage patterns are not sustainable. In this regard, several researchers, including Pollet, Stafell, and Adamson (2015) and Msibi and Kornelius (2017), view the implementation of biogas technology as the essential strategy for resolving South Africa's problems with energy insecurity and the environment. Adoption psychologically requires the application of a person's capacity for environmental awareness. When a person is knowledgeable and conscious, the adoption process can begin. Rejection could come next, or the adoption choice could be made. There are certain contextual aspects that affect the adoption process, including social and cultural context, climate, geography, and economic situations (Botha and Atkins 2005). To guarantee competence in long-term monitoring of biogas digesters, local populations need to be aware of the technology.

The goal of this initiative is to demonstrate to the government the value of biogas technology through the implementation of pilot biogas systems in agricultural areas (Wargert 2009). Furthermore, it is crucial to remember that a person's knowledge of technology reflects their opinions and attitudes about it (Meijer et al. 2015). Furthermore, Gakuu, Njoroge, and Nyonje (2013) noted that people's responses to biogas technology simply depend on their views or perceptions about its use and price, among other things. Perceptions may be favourable, leading them to invest in technology, or unfavourable, making them less likely to do so. The adoption of biogas digest by rural families is hampered by socioeconomic considerations, according to comprehensive research conducted across Sub-Saharan Africa (Mwirigi et al. 2014). Based on the amount of available disposable income in the home and priorities that necessitate allocating limited resources within the household, household incomes are an important factor in selecting whether or not to invest (Modiselle et al., 2005). The likelihood that a household will adopt or invest in biogas increases with household income.

We analyse additional factors that influence the adoption of biogas technology taking into account the significant advantages that biogas digesters provide low-income rural households, as stated in the previous sections. In other regions of Africa, it has been determined that the size of the household, the number of cattle possessed, and the size of the landholding are among the things that can have an impact (Shallo, Ayele and Sime 2020). Furthermore, the level of education has a significant impact on the adoption of biogas due to the expanded knowledge that comes with education (Puzzolo et al. 2016). In addition, effective leadership has been asserted to be crucial for the spread of biogas technology. The community looks to the innovators and adopters as the gatekeepers and decision makers when deciding whether or not to adopt the new technology (Rogers 1995).

2.6 Overview and Current Status of Biogas Implementation

Approximately 35 billion m3 of equivalent methane - or 59 billion m3 of biogas - are produced globally each year, with the European Union (EU) contributing approximately half of that amount (Norouzi & Dutta, 2022). As a result, biogas production in developing nations has been inadequate and has made little progress. In terms of biogas production, developing nations lag behind their developed counterparts. Due to varying socioeconomic situations, technological advancements, degrees of development, and endowments of natural resources, the deployment of biogas in developing countries differs substantially between nations (Zupančič et al., 2022). China has the most household biogas plants in the world (Igliski et al., 2020), and small-scale domestic biogas plants are widely implemented in these countries (Nevzorova, 2020). However, by building medium- and large-scale biogas facilities, most emerging nations are increasing their pace of growth to grow their biogas production. This section addresses biogas implementation and trends in Africa and the Asia-Pacific region, with a focus on emerging nations in these regions.

2.6.1 Asia-Pacific Countries (APAC)

Biogas is an important treatment method for food waste in countries with good waste management and no landfills, such as Germany and Sweden. However, other nations do not combine waste management with biogas production. For example, the East Asia and Pacific region produces roughly 270 million tons of trash annually, but biogas adoption is still in its infancy. The implementation of biogas in China began in 1974, providing energy to rural areas and boosting their economies. Approximately 1.6 million biogas plants were erected, but by 1980, more than half of these plants had failed due to inadequate digester design. Between 1996 and 2012, the government committed a total of around 31 billion RMB to the development of biogas (Khan et al., 2021). Despite this significant investment, progress has been slow; research revealed that only around 19% of the biogas potential of China's rural areas has been used (Nurul et al., 2018). However, according to Glivin et al. (2021), around 38.5 million residential biogas digesters were installed in 2010 with an annual production of 13.08 billion m3, which grew to 41.93 million and 15.8 billion m3 in 2015, respectively (Khan et al., 2021).

According to estimates, the yearly target value for biogas generation in 2020 will be 20.7 billion m3 and 43.94 million household digesters (Khan et al., 2021). China has made considerable strides in the application of biogas, particularly through agricultural-based initiatives, and production is currently rising as a result of the introduction of industrial-size digesters. Despite the progress made, there are still issues with policy, pretreatment technology, an unreliable industrial chain, norms and specifications, and technical issues caused by defective or sub-par digesters (Angelidaki et al., 2018). In order to improve people's access to energy services, India's biogas programme was formed in 1981 under the National Project on Biogas Development (NPBD). The National Biogas and Manure Management Programme (NBMMP) was launched in 2005 in an effort to address some of the issues that had been encountered, such as poor construction and material quality and a lack of accountability for failure. Only 40% of the anticipated potential of 12 million biogas plants have yet been installed, or roughly 5 million (Giwa et al., 2020).

Fixed dome reactors, floating drum reactors, and balloon or tube digesters are the three types of biogas reactors most frequently used. After researching the operation of current reactors and the difficulties encountered, the FOV textiles plug flow textile-based reactors have been introduced. In India, several of these recently developed reactors have been constructed to process mixed feedstock, cow dung, human excreta, and food waste. Although it is socially and culturally forbidden in some locations to use biogas made from animal or human waste, this is not acceptable for the use of biogas. Despite progress in India's biogas deployment, the trend is not encouraging. India now produces roughly 2.07 billion m3 of biogas annually, which is about 4% to 7% of its potential of 29 to 48 billion m3 (Williams et al., 2022). India continues to have several operational problems, particularly in the chilly regions (Williams et al., 2022). Wider adoption faces obstacles related to process monitoring and control, mixing, poor biogas yield, cost of building a biogas plant, plant maintenance, and dependability.

Over time, Nepal's use of biogas has risen; the government's agricultural department erected about 250 units in the middle of 1970. (Kaur et al., 2022). After that, the Netherlands provided financial support for the Biogas Support Programme (BSP), which resulted in the installation of roughly 6824 biogas plants between 1992 and 1994, a total of 174,591 in 2009, and currently more than 300,000 biogas plants. Government and foreign sponsors have helped spread the trend, although the technology has not yet been fully adopted; biogas only represents 0.6% of the overall energy share (Hasan et al., 2022). Furthermore, Nepal has the capacity to install more than 1.9 million plants, but only about 9% of this total capacity has been used. However, a survey has shown that carbon trading is currently helping to support biogas technology in Nepal, with VER, which is run by the World Bank, generating more than 600,000 USD annually (Sirothiya & Chavadi, 2020). Lack of water and sufficient feedstock, freezing temperatures (about 10°C) in Nepal's hilly terrain, installation expense, and awareness are the main problems of the country (Lewicki et al., 2018).

With an annual discharge of around 85 million tons of livestock waste, biogas technology has been used in Vietnam for more than 30 years. The SNV Netherlands Development Organisation installed 152,349 biogas plants overall in 2012; this number increased to 500,000 in 2015. Vietnam's annual biogas energy potential was projected by Roubk et al. (2018) to be 120 TJ in 2015 and to increase to 127 TJ in 2020. However, due to difficulties with technical services, funding, insufficient operational procedures, and a lack of relevant information, the promise has not been fully realised (Anwar et al., 2021). Being the major producers of palm oil, Indonesia and Malaysia have enormous potential for biogas from palm oil mill effluent (POME). From POME, sewage treatment plants (STP) and municipal solid waste (MSW), Indonesia has a total potential annual production of 4.35 billion m3 of bio-methane, while Malaysia has a total potential annual production of 3 billion m3 of bio-methane from similar waste streams. By 2025, Malaysia's use of renewable energy is expected to increase from 2% to 20%. (Tagne et al., 2021).

Despite the potential and prospects, there are several obstacles to biogas implementation in Indonesia and Malaysia related to funding, government coordination, programme coherence, and planning. The Pakistani government began to implement biogas in the country in 2000; as of right now, 1200 biogas plants have been set up (Jelínek et al., 2021). An additional 10,000 biogas plant installations are anticipated in the next five years, with the goal of using 27% of the nation's biogas potential. In Pakistan, plant failure has been attributed to poorly maintained biogas digesters (Zheng et al., 2020) Through the National Biodigester Programme (NBP), the SNV Netherlands Development Organisation and the Cambodian Ministry of Agriculture, Forestry, and Fisheries (MAFF) launched Cambodia's biogas initiative in 2016. Through the Cambodia Climate Change Alliance (CCCA), the NBP initiative received financial support from the governments of the Netherlands, Germany, the Czech Republic and the EU. In addition, the project was funded by Carbon Finance, which received revenue from the sale of verified carbon reductions.

As a result, 294 biogas digesters were erected in 2006, and by 2017, there were more than 26,000 biodigesters (Pandyaswargo et al., 2019). The full utilisation of Cambodia's biogas potential has been said to be hampered by a number of significant obstacles, including lack of understanding of the technology, distrust of the technology, adverse weather, and building problems.

2.6.2 African Countries

The African Biogas Partnership Programme brought biogas technology to the continent. In Burundi, Botswana, Burkina Faso, Cote d'Ivoire, Ethiopia, Ghana, Guinea, Lesotho, Namibia, Nigeria, Rwanda, Zimbabwe, South Africa and Uganda, several biogas digesters have been installed (Clemens et al., 2018). According to estimates, Nigeria, the most populous nation in Africa, has a biogas potential of 6.8 million cubic metres per day from animal manure and 913,440 tons of methane from MSW, which is equal to 482 MW of electricity [44]. By 2030, Nigeria is expected to produce 171 TJ of biogas energy (Yimen et al., 2018). Despite the promise of biogas in African nations and the viability of the technology having been demonstrated by various programmes, the technology is not widely used and large-scale applications have not been successfully implemented (Kemausuor et al., 2018; Dumont et al., 2021).

2.7 Challenges to Biogas Implementation in Developing Countries

Locations, forms, cost structures, and usage patterns vary in the deployment of biogas; these variations depend on the level of development of the country (Patinvoh & Taherzadeh, 2019). The correct execution of policies, funding, technical services, sustainability, awareness, and education, all essential components of effective implementation and essential to realise the full potential of biogas, present obstacles in developing countries. In light of these difficulties, this section lists the problems faced by emerging nations and suggests tactical solutions for resolving them in the subsequent session.

2.7.1 Technical and Infrastructural Challenges

Unlike industrialised nations, the establishment of a sustainable technology continues to be a significant obstacle to the application of biogas in poor nations. Developing countries have abundant biomass, but cannot use these resources effectively due to a lack of infrastructure that can support the necessary technology. Additionally, the success of implementing biogas depends on how well users comprehend technical fundamentals (Obaideen et al., 2022). Combining biogas technology with eco-agricultural technology has been challenging, since most biogas operators have not received enough technical training on biogas production (Aziz et al., 2019); this has also led to low biogas production. For example, the yield of the biogas produced is determined by the composition of the feedstock (organic and nutrient content, contaminants and potential inhibitors), which can also cause the failure of the entire biogas process. Additional factors contributing to low production and digester failure include a lack of technical ability to build high-quality digesters, a lack of understanding of the correct management of these digesters, and ineffective mixing capacities (Lu & Gao, 2021).

The performance of a biogas process is negatively affected by process instability, which occurs in biogas digesters as a result of temperature variations because the activity of the microorganism is decreased if the temperature is above or below its ideal range (Diouf & Miezan, 2019). There is no reliable technology to control operating temperature throughout winter, especially in countries of cold climate. When the temperature is below 15°C, digesters without insulators are ineffective; a prominent example is Nepal, which has a chilly climate (about 10°C) in a hilly terrain (Afridi & Qammar, 2020). Many developing nations have a water supply problem. Wet fermentation is a prevalent process for producing biogas; however, it uses excessive amounts of water, which is problematic for poor nations with limited water resources. A challenge to transporting and applying digestate to agricultural land is the huge volume of biogas residue.

2.7.2 Financial Challenges

The growth of biogas implementation in developing countries is severely constrained by a lack of funding. A self-built home-scale biodigester with a 50 kg daily input capacity is currently estimated to cost around $1500; this is a significant investment for those with limited financial resources when taking into account other costs, such as those associated with storage tanks, operations, purification, biogas compressors, and maintenance (Saidmamatov et al., 2021). For optimal biogas production, mechanical pretreatment is occasionally necessary before the digestion process; however, the cost of this is also fairly high (Gao et al., 2019). Additionally, industrial scale applications are necessary for the investment to be profitable, and the equipment required for such applications is very expensive and typically costs thousands of dollars; the price of a small industrial biodigester with a daily input capacity of 2000 kg is reported to range between $500,000 and $1,000,000 (Singh et al., 2020). Furthermore, the lack of technical professionals results in expensive maintenance costs. It is quite difficult to obtain commercial loans in underdeveloped nations, especially in rural areas, to invest in biogas infrastructure.

2.7.3 Policy and Political Challenges

Most developing countries lack effective trash collection and sorting systems. Trash managers frequently combine several waste streams and dump them in uncontrolled landfills or burn them in the open (Osei-Marfo et al., 2018). There is no defined policy on the utilisation of renewable energy sources and environmental policy is relatively weak (Dehkordi et al., 2020). Another significant obstacle preventing the adoption of biogas from progressing is the lack of government commitment and the inconsistent continuation of previous biogas programme projects under different governments (Mateescu & Dima, 2020). Corruption is a different issue that makes the implementation of biogas more expensive both financially and operationally, reducing the return-on-investment rate (Mukeshimana et al., 2021; Rasapoor et al., 2020).

2.8 Strategic Measures to Improve Biogas Implementation

In this section, methods that industrialised nations have successfully implemented are discussed. Some of these tactics must be adopted by developing countries to encourage the development of biogas implementation.

2.8.1 Technology and Education

Developing nations must create their own, more affordable digestion systems with simple installation and operation methods. It is important to streamline technical services and biodigester management so that people can buy high-quality energy at a reasonable price (Xue et al., 2020). Conversion procedures should also be made simpler to cut costs associated with production. It is important to promote international collaboration and the exchange of best practises. Additionally, steps must be taken to improve the management of biogas plants and follow-up services (Mateescu & Dima, 2020). Without adequate education, this is not possible. For example, if inexpensive household digesters were the answer for villages, say villages in a developing nation, the main obstacle would be that the owners would not be familiar with how to run the digesters. It indicates that if the government offers support services and education, it can greatly aid in the efficient functioning of these digesters.

2.8.2 Funding

For considerable changes, funding from non-governmental organizations and the government is required. Many years of central government funding through local investment programmes (LIP) and climate investment programmes (KLIMP) have allowed considerable advances in the use of biogas for energy generation and automobile fuel in countries like Sweden, Denmark, and Germany. In order to make Vester Hjermitslev in Denmark energy self-sufficient, the first plant was built there with almost all public funding: a 4 million DKK grant from the government and an 8.4 million DKK loan from the North Jutland County Council (Chrispim et al., 2021). Additionally, there are loan programmes with low long-term interest rates and investment subsidies for centralised biogas facilities that can cover up to 40% of expenditures. Another viable alternative to support biogas implementation in developing countries is carbon trading through Voluntary Emission Reduction (VER) managed by the World Bank (Güsewell et al., 2019; Karlsson, 2019).

2.8.3 Policy

Policies are required to encourage the production of biogas for the generation of electricity in developing countries. Federal, state and municipal governments must create cutting-edge regulations that attract investment and promote energy generation flexibility. Additionally, sound policy should be maintained; a change in government does not automatically result in a change in policy. In wealthy nations, policies such as feed-in tariffs, net metering, virtual net metering, and tax incentives have greatly aided the development of renewable energy sources (Tabatabaei et al., 2020). Tax exemptions or reductions on fossil fuels and rules requiring filling stations to offer at least one renewable fuel are among the policies in Sweden that favour renewable transportation fuel (Kiselev & Magaril, 2022).

2.8.4 Public Awareness Campaigns and Research and Development

People need to be aware of the value of properly managing the wastes they produce on a daily basis and the advantages of the biogas they can produce. Continuous counseling and teaching are needed on proper waste management, trash reduction, reuse for a longer period of time, recycling to create new products and recovery of waste energy in communities, schools, and market places. Governments should encourage research and development (R&D) by making sure that universities and businesses in emerging nations work closely together. The fact that imported technology does not align with regional needs and accessible infrastructure is a significant barrier to the development of biogas plants. R&D is therefore required to create new regional technologies or to alter those that already exist. Universities can carry out pilot projects to assess the viability of the technology and create the best conditions for a successful adoption. After that, companies can use the technology.

2.9 Empirical Literature

There is a need to turn to renewable resources to address the growing demand due to the energy crisis in Pakistan and the growing demand for energy for economic and industrial development (Jabeen et al., 2019). Concern is being raised about the rising demands for renewable energy technologies (RETs) and their production capacity as a result of conventional energy resources' detrimental effects on the environment's cleanliness, which pose a serious threat to the survival of all life on Earth (Awan & Khan, 2014). In a different study, Khalil & Zaidi (2014) outlined the causes of Pakistan's current energy shortages. Their research, which also looked at the relationship between energy demand and supply in various contexts, came to the conclusion that solar energy, as opposed to wind energy, was better able to meet home and industrial energy needs. Energy shortages, according to some, are responsible for the switch from traditional energy to biogas generation technology (BGT) (Bekchanov et al., 2019). Another study on residential energy use looked at how BGTs are likely to handle a variety of challenges, including managing waste materials, producing electricity, and concerns about the environment and socioeconomic situations (Fetanat et al., 2019).

By selecting 200 families as a sample, Jan & Akram (2018) examined the readiness to use the BGT system in the rural Khyber Pakhtunkhwa province (KPK) of Pakistan. To this end, a probit regression model (hereinafter, PRM) was used to identify the variables that affect people's desire to accept BGTs. Their findings demonstrated that the primary elements that greatly influence the readiness to use BGT for energy usage are load shedding, awareness of the costs and benefits of using biogas energy, and the effect of load shedding on children's education. By conducting a survey in rural areas of the Tigray region and using logistic regression analysis, Kelebe et al. (2017) conducted a study in Ethiopia to take into account the variables that influence BGT. They came to the conclusion that several important criteria, including socioeconomic, demographic, female domination, age, education, collecting time, and distance, favoured the diffusion of biogas. Similarly, to this, Ahmad et al. (2017) conducted a cross-sectional study in Yogyakarta, Indonesia, selecting a sample of 351 homes, both adopters and non-adopters, and analysing the effects of BGT adoption on households.

According to their findings, the adoption of BGT was influenced by a decrease in the amount of firewood used and the amount of time required to collect wood. In a related study, Uhunamure et al. (2019) found that factors such as age, education, yield production, financial resources, cow ownership, gender, awareness, accessibility to technical specialists, house size, and income had a large impact on the adoption of BGT. For this, they used a logistic regression model to conduct the analysis on a sample of 200 families from the South African province of Limpopo. It has been reported that the use of BGT has decreased the costs associated with energy usage. As a result, there was a decrease in the cost of buying wood or charcoal, which led to financial savings. Along with time savings and reduced job requirements, it also had financial advantages (Khalil & Zaidi, 2014). Additionally, a study conducted in Nepal found that between 1992 and 2006, there were an additional 0.9 million employment openings in the BGT sector. Furthermore, by creating biogas plants, villages, builders and construction companies benefited financially (Roubk et al., 2018). Since they are the women who spend all day gathering wood for fuel in villages, they are prevented from participating in other productive activities (Kelebe et al., 2019).

Due to this, the use of BGT could reduce the time needed for fuel collection. Furthermore, Abbas et al. (2017) discovered that adopting BGT is advantageous in terms of both money and the environment in a study they carried out in the Faisalabad area using a sample of 160 homes using a stratified random sampling technique. Similarly, to this, Yasar et al. (2017) examined the effects of the use of household biogas plants on health, financial position, time savings, and energy savings. The use of biogas plants had a significant impact on energy and time savings, as women did not have to walk outdoors to collect wood for fuel, saving time and money, according to the findings based on data from various homes. The advent of liquid or gaseous renewable energy fuels has reduced the use of solid biomass, reduced air pollution, and helped improve people's health in terms of environmental pollution and human health risk (International Renewable Energy Agency, 2017). It is thought to be helpful in reducing climate change because they can advance economic and social development and minimise harmful effects on human health and the environment.

For example, increasing household biomass can reduce air pollution and have a positive impact on lowering human health risks (Intergovernmental Panel on Climate Change, 2011). Because electricity production was the largest contributor to air pollution and a host of environmental problems, which ultimately contributed to poor air quality, the adoption of RETs could result in a decrease in greenhouse gas emissions, which would have a favourable influence on health. Therefore, switching to renewable energy sources (like biomass) can improve air quality, which can benefit human health (reducing cardiac and respiratory ailments) as well as the ecosystem and increase production yield. The study was then conducted in Uganda, Kenya, and Tanzania, three nations in Africa. The objective of the study was to promote the acceptability of BGT in rural communities in sub-Saharan Africa. The data was obtained through surveys and interviews. Its main findings showed that the use of biogas improved yield and living standards, decreased deforestation, and lowered health consequences (Clemens et al., 2018). Last but not least, despite efforts made at all levels to promote the use of BGTs, including the provision of subsidies and the extension of the delivery infrastructure, BGTs continue to face obstacles and constraints in their expansion process (Jan et al., 2018).

Other issues, such as capital expenditures, educational attainment, capital grants, technological considerations, and gender, are prevalent barriers in China, Kenya, and Bangladesh to the adoption of biogas systems (Kardooni et al., 2018). The consumption of slurry, quality control and the use of foreign funds were taken into account in countries where most of the population relies on the use of wood and agricultural waste as fuel to cook food (Kardooni et al., 2018). In addition, Dendup (2019) claimed that education was a key element in promoting clean cooking fuels. In this regard, a unique survey was carried out in rural Bhutan and its findings showed that people were 39% more inclined to embrace clean cooking fuels if they had more information. Additionally, increasing the use of BGT depends on the education of women. For example, using BGTs to bake the traditional bread known as "Injera" in Ethiopia strongly encourages their adoption (Farooq & Kumar, 2013). BGTs are said to have numerous applications, including heating, cooking, and power generation. In this regard, a sample from Limpopo consisting of 72 adopters and 128 non-adopters has been taken (South Africa).

For this, a logistic regression model was used to examine the data. The findings showed that factors including household awareness, house size, proximity to a source of fuelwood, number of cattle, and house size are major factors that encourage acceptance and use of BGT (Uhunamure et al., 2019). Main-stream works mainly focused on identifying the drivers of technology adoption but neglected to take into account the crucial influencing factors (hereinafter CRIFs) of BGT utilisation (Zafar et al., 2018). To be more precise, no research has ever been found to investigate households' preference-based CRIFs of BGT utilisation (Rauf et al., 2015; Van Dael et al., 2017). It is unknown whether previous studies in this field have used the propensity score matching (hereinafter PSM) method to conduct analysis (Ali et al., 2013). Last but not least, prior research neglected to take into account the generated benefits based on financial, health, environmental protection, and crop harvest, which may be what motivates households to utilize BGT (Iqbal et al., 2013). Therefore, the mainstream studies provided important gaps that the current study may fill.

This paper has made an effort to empirically evaluate the families' CRIFs of BGT utilization in light of the aforementioned research gaps. This study examined how CRIFs, which are based on family preferences as well as socioeconomic and infrastructure factors, affect how BGT is used at home in Pakistan. The information is gathered using a sample of 695 homes (users and non-users) from seventeen tehsils, which are the administrative subdivisions of the Punjab region of Pakistan. A PSM as well as PRM methodologies have been used for the analysis. The groundbreaking findings have extensive positive policy ramifications. The remainder of the study is organized as follows: The theoretical framework based on innovation adoption is explained in Section 2, the data collection and research technique are described in Section 3, the findings and discussions are based in Section 4, and the research is concluded and the policy implications are documented in Section 5.

3. AIMS OF THE THESIS

The main aim of the current study is to investigate the factors influencing household decisions on the adoption and use of biogas technologies and the implementation benefits in terms of the socio-economic, environmental, health and climate issues in relation among households in rural areas of the Offinso North district in the Ashanti region of Ghana.

3.1 Specific objectives

Specifically, the current study seeks:

1. Assess the level of knowledge and perception of households about the use of biogas technology.
2. To investigate whether factors influencing household decisions on adoption and use of biogas technology have any effect on socio-economic, health, environment and climate aspects and identify the main challengers hindering the adoption of biogas technology.
3. Assess the approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure.

3.2 Research questions

The current study seeks to answer the following questions:

1. What is the level of knowledge and perception of households about the use of biogas technology?

2. What effect does influencing factors for household decisions on adoption and use of biogas technology have on the socio-economic, health, environment and climate aspects and identify the major challengers hindering the adoption of the biogas technology?
3. What are the approaches used by the government and NGOs in the development, designing and implementation of biogas technology in order to establish the causes of the system failure?

4. METHODS

This section contains research design, research purpose, population, sampling size and sampling technique, data collection, data collection sources, data analytical tools, reliability and validity of data, and ethics.

4.1 Research design

The design of a study is an important factor in determining how data will be collected, measured and evaluated, thus directly impacting the results of the study. It is therefore imperative in piloting every effective research (Bryman & Lilley, 2009). Research design is seen as the structure, systematic plan or gum that embraces all the components in research together. It is the conceptual within which research is conducted by identifying the blueprint for collecting the right information, conducting measurement, and analysing the research data. In literature, traditionally, there are three key designs to research: quantitative, qualitative, and mixed method. Although the distinctions between the three are mostly blurred because the strategies are mixed and overlap (Creswell, 2009), there are still some variations between the research-guiding methods. The qualitative research is simply the techniques associated with gathering, analysing and presenting narrative information (Tashakkori and Teddlie, 2009). Used primarily to explore largely subjective aspects of phenomena like attitudes, beliefs, and opinions, qualitative research aims at understanding, exploring insights, and describing social occurrences.

Quantitative research, another popular approach to research, offers researchers a method of testing objective theories by examining the relationships among variables by dealing with numeric data that may be organized into various data types, quantitative research places emphasis on objective measurements rather than subjective, and describes and tests relationships through quantifiable information gleaned from the data (Hair et al., 2009). Quantitative designs are often limiting to respondents, as closed-ended questions are regularly utilised to gain information, preventing the acquisition of certain valuable insights. Mixed-method research, a third option for the design of studies, can be considered an amalgamation of the former two methods. Therefore, it combines the strengths of both qualitative and quantitative research. Bryman (2006) explains that using a mixed method for the design of a study offers several advantages including: corroboration of findings from two independent sources of data; aiding interpretation of one source of data using data from another; the ability to study different aspects of a phenomenon simultaneously; and, filling in gaps in knowledge using data from another source. Therefore, the research design for the current study was quantitative, as many previous studies in the field have been (Ibrahim et al., 2014; Geter Sr, 2010; Willis et al., 2020).

4.2 Research purpose

Research has a key objective that it seeks to accomplish, and the literature agrees that research may attempt to explore a new or relatively unsearched phenomenon, to simply explain an existing situation, or to explain an existing phenomenon (Neuman, 2011). Exploratory research has been defined as 'research intended to develop initial ideas or insights and to provide direction for any further research needed' (Hair, Bush, and Ortinau, 2006). An explanatory study goes beyond simply narrating what already is evident, explanatory studies go a step further to determine causes and reasons. It asks “Why?” and “How?” Hence, to tease out underlying factors that may not be immediately obvious in exploratory and descriptive studies. Explanatory studies attempt to explain observed causal relationships between variables. Descriptive research design is statistical research that describes the phenomena as they exist. It is used to identify and obtain information about the characteristics of a certain problem. Descriptive research was implored for the research work which according to Kothari (2004) is concerned with recounting the features of a unique person or a group. The descriptive method of research is beneficial to researchers due to its litheness.

The descriptive method of research is made up of three (3) types namely; observational, correlational, and survey. To achieve the objective of this study, explanatory and descriptive research methods were deemed feasible. The study therefore adopted a quantitative research method, with surveys using questionnaires to obtain the opinions of the respondents to formulate the research findings.

4.3 Population

Ghana is a western African country with an economy orientated toward agriculture that contributes greatly to its gross domestic product and small-scale domestic trading (Raheem et al., 2021). It shares a common border with the Republic of Togo in the east, Burkina Faso in the north, the Ivory Coast in the west and the Atlantic Ocean in the south (Chirawurah et al., 2022). The Ghana population was estimated to be 31 (31) million in 2021 on Monday 3 May 2021, based on the elaboration of the World metre of the latest United Nations data (Kortei et al., 2021). The total land area is 227,540 km2 (87,854 sq. miles). The population of 56.7 % of people live in urban areas (17,625,567 people in 2020). The country is divided into six agroecological zones because of the climate, reflected by natural vegetation, and influenced by soils. These agroecological zones from north to south are the Sudan Savannah Zone, Guinea Savannah Zone, Transition Zone, Semideciduous Forest Zone, Rain Forest Zone, and the Coastal Savannah Zone. The research would focus on rural households in the offinso North (Ashanti region) in Ghana, and stakeholders in government and non-government institutions.

Offinso North District is one of the 27 Administrative Districts of Ashanti Region Created in the later part of 2007; it is located in the extreme NorthWestern part of the Region. The district lies within longitude 1˚45w and 1˚65w. Farming is the predominant Occupation of the people in the district. The sector represents more than 70% of the economically active labour force (Nkansah, Serwaa, Adarkwah et al., 2020; Nkansah, Serwaa, Osei-Boakye et al., 2022; Anyimah et al., 2021). However, about 60% of all engage outside the Agricultural sector still practise Agriculture as a subsidiary activity. The current total farming population is around 30,000 comprising 15,030 male and 14,970 females. The Youth in agriculture (people between the ages of 15-34 years) constitute 30% of the farming population is a great potential for sustainable Agricultural production. Adoption is described as "initial technology acquisition and use for less than one year from the acquisition" by Puzzolo et al. in 2016. The dependent dummy variable in this study was adoption. For families that had a working biogas technology, a value of "1" was given, and for those who hadn't, a value of "0."

The sampling frames consisted of houses that had purchased biogas equipment a year earlier. To get precise information regarding the problem, biogas adopters with at least a year's worth of biogas installations were chosen. In addition, households were expected to be more experienced and knowledgeable about the advantages and disadvantages of technology. This was done to evaluate the parameters that influence households' decisions to adopt biogas technology in the research location. Households that had functional biogas plants were considered adopters, whilst those without such plants were considered non-adopters.

4.4 Sampling size and sampling technique

A sample is often made use of when a census of the entire population is not possible (Cooper & Schindler, 2000). A sample size of a survey most typically refers to the number of units that were chosen from which data were gathered (Lavrakas, 1998). The sample size was 23 adopters of the household and who were willing to respond to the questionnaire in the Offinso North District. A sampling technique is the name or other identification of the specific process by which the entities of the sample have been selected. Hair et al. (2006) reveal that a sample size selected by a researcher has an influence on the statistical tests that can be generated and the extent to which generalisation can be made. It is therefore important for the researcher to apply the right sampling technique in order make the best of selection of sample for the study. Malhotra and Singh (2006) identified two main sampling techniques, thus probability and non-probability. Non-probability sampling method was used to select participants. This is a type of sampling method in which the sample units are selected based on personal judgement or convenience.

Non-probability sampling was used in the choice of respondents regardless of their cumulative number of households. The researchers thus employed a convenient sampling technique under the non-probability sampling method. This technique was appropriate for this study, because it was less time consuming and cheaper, and the researcher also provided the opportunity of selecting experts to share their open views on the questions posed.

4.5 Data collection

Data collection is defined as a systematic process for gathering and measuring information on specific research variables which helps a researcher to address research questions, assess hypotheses and analyse data (Mkandawire, 2019). A questionnaire is a series of questions that are asked of individuals to obtain statistically useful information on a given topic. They are a valuable method of collecting a wide range of information from a large number of individuals, often referred to as respondents. Adequate questionnaire construction is critical to the success of a survey. To answer the questions of the study, structured questionnaires were circulated to households within the Offinso North District. To establish relations with the respondents, the researcher self-administered the questionnaires and in return encouraged them. The questionnaire was handled interactively and local language was used where possible, to provide an interpretation of appropriate answers. The first part of the questionnaire captured the demographic characteristics of the respondents including their age range, gender, and educational level. The second section consists of items that measure the main constructs of the study.

4.6 Data collection sources

Data may be collected from two main sources for a study (Saunders et al., 2009). These are known as primary and secondary sources of data and may be used either exclusively or in conjunction to gain information for the research.

4.6.1 Primary data

Primary data has been described by scholars as “original data” collected directly from first-hand sources and gathered specifically for the purposes of answering the research question at hand.

Therefore, it is usually collected through a data collection instrument specified and designed by the researcher in accordance with the research objectives and questions that the study seeks to address. The current study was based on primary data, which was gathered using a questionnaire as a data collection instrument.

4.6.2 Secondary source

Secondary data, on the other hand, comprises information that has already been collected for another purpose, but which is still relevant for the study. Such data are often used to provide additional information on the research. In this study, secondary data helped to review the literature and support the arguments for the findings made.

4.7 Data analytical tools

The data collected were subjected to analysis and examinations that helped the researcher to come to the right conclusions and made the right recommendations. In this research, the analysis of the data collected was based on primary quantitative techniques. These methods included descriptive methods and statistics to present the mean demographics of the respondents and standard deviation. The collected data has been edited for error detection and erasure. This process was done at the same time as data collection in the field. Then it was coded according to categorisation for entry into computers for data analyses. To examine the level of knowledge and perception of households on the use of biogas technology, to investigate whether the influencing factors for household decisions on adoption and use of biogas technology have any effect on the socio-economic, health, environment, and climate aspects and identify the major challengers hindering the adoption of the biogas technology, and to assess the approaches used by the government and

NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure, a statistical method was adopted.

After the data was collected, it was coded and keyed in statistical package for social sciences (SPSS v.26). The data was cleaned to ensure that it was correct. Scale-based variables were checked to ensure internal consistency, after which scores were aggregated to determine the mean score for each respondent. Descriptive statistical techniques were used for the data analysis. Hair et al., (2016) proffered that descriptive statistics makes it possible to present results numerically and graphically presenting information that gives an overall picture of the data collected. The researcher will use SPSS v.26. SPSS is a software that can help analyses focusing on descriptive statistics to be done. This ensures that mean and standard deviation of the items measuring the objectives of this study are obtained. Respondents' agreement to the items will also be analyzed to determine the results of this study.

4.8 Reliability and validity of data

4.8.1 Reliability

This refers to the consistency or dependability of a measurement technique (Shao et al., 2019). More specifically, reliability is concerned with the consistency or stability of the score obtained from a measure or assessment technique over time and across settings or conditions (Sürücü & MASLAKÇI, 2020). If the measurement is reliable, then there is a less chance that the obtained score is due to random factors and measurement error. Reliability in its simplest form is about the relationship between separately generated sets of scores, such as the scores on two different evaluation instruments. Reliability, therefore, is generally expressed as a coefficient of correlation, a statistical examination that tells us about the relationship between two sets of values or variables. There is sufficient reliability when the correlation coefficient is 0.80 or higher.

4.8.2 Validity

According to Mellinger and Hanson, (2020), validity means to what degree an instrument tests what is to be measured. Validity has a multitude of dimensions and approaches to measurement. Two statistical analyses will be conducted to verify the integrity of the questionnaire. Initial check is Criterion-related validity test (Pearson test) which measures in one field and the entire field the correlation coefficient between each paragraph. The second analysis is structure validity test (Pearson test) that evaluated the validity of the questionnaire framework by assessing the validity of what area and the whole questionnaire. The correlation coefficient measures the same degree of correlation between all the fields in the questionnaire (Hayashi et al., 2019). The researcher ensured validity by using questionnaires from already existing questionnaires. This is because the questionnaires have been used for more than once.

4.9 Ethics

Ethics form the major aspects of research and important consideration in every good research and this particular study has no exception. Ethics can be seen as standards or norms of conduct that distinguishes right from wrong. This also helps to decide which practises are acceptable or undesirable. According to Centre for Innovation and Research in Teaching (CIRT), ethical consideration in research has two very important elements. Originally, 'ethical principles' prohibit evidence from being created or manufactured.' thereby promoting the quest for information and truthfulness which is the prime objective of every research. Second, it is also "essential to cooperation" as it represents an environment of researchers' esteem, transparency, and shared respect. This is also imperative when it comes to issues concerning the exchange of information, shared authorship, trademark, secrecy and other matters. Additionally, researchers must also follow the ethical guidelines of public confidence, support, and faith. The general public wants to have confidence and make sure that researchers follow the applicable criteria on issues such as human rights, animal protection, law enforcement, conflict of interest, peace, quality of health ', etc.

The research study has also addressed the following ethical issues with regards to the survey: First, the right of the respondents to privacy is important in conducting any research because the information provided by the respondents must be kept private, especially their individual identities. This is necessary to remember that the identities of the respondents will be kept hidden at all times, unless they can make their identification known. The study trumpeted this issue of the respondents' rights to privacy and has done everything possible to protect the rights of the respondents who actually participated in data collection processes. For this reason, the questionnaires avoided any possible ways to reveal the identities of the respondents. Furthermore, the use of deception according to the researcher is unethical and should not be entertained. It is ethically wrong for any researcher to convey false information to respondents just to get their views or get them to answer the research questions. The researcher did not consider the use of deception during the data collection and analysis processes. The research study was aware of this particular ethical issue and at nowhere has the researcher indulged in any act of deception or falsification of data.

The data collected and the analysis conducted reflect the response and opinions gathered from the respondents at the research site. Furthermore, respondents were informed before distributing the survey questionnaires to them. The researcher actually explained the motive of the research and the important things that the respondents supposed to know. The researcher also sent a formal letter to all adopters in the hosuehold to request permission to collect data, which was granted by the organisation. Furthermore, as part of the measures, the researcher told the respondents not to sign their names to maintain confidentiality, and their responses for the sample will forever remain secret. In addition to maintaining secrecy, the researcher also assured the respondents that nobody outside the study will ever see the study completed. The researcher will gather and analyse surveys and submit the findings. All the information regarding the survey will be kept in the best possible confidential level. A confidentiality letter between the company and the researcher was signed in a timely manner to give more confidence to the company with respect to the survey conducted by the researcher. Last but not least, the researcher believed that the respondents were honest in their responses to the survey and that no amount of inducement was perpetuated on the respondents.

The respondents knew what they were answering regarding the questionnaires and provided answers that were honest to the best of their knowledge. The researcher also during the data collection process was frank and honest in his approach to the respondents. No amount of inducement was offered to the respondents. Finally, the researcher exhibited a high level of objectivity in reporting and analysing the research data. Data analysis was performed based on true accounts of events that occurred during the research survey and data collection processes. The responses provided by the respondents were properly captured and reported according to the results obtained from the captured data.

5. RESULTS AND DISCUSSION

5.1 Demographic data of respondents

Figure 1 shows that 1 household adopter was below 20 years of age, 11 household adopters were 20-29 years of age, 7 household adopters were 30-39 years of age, 3 household adopters were 40-49 years of age, and 1 household adopter was 50-59 years of age. Household adopters ranged from 20-59 years of age.

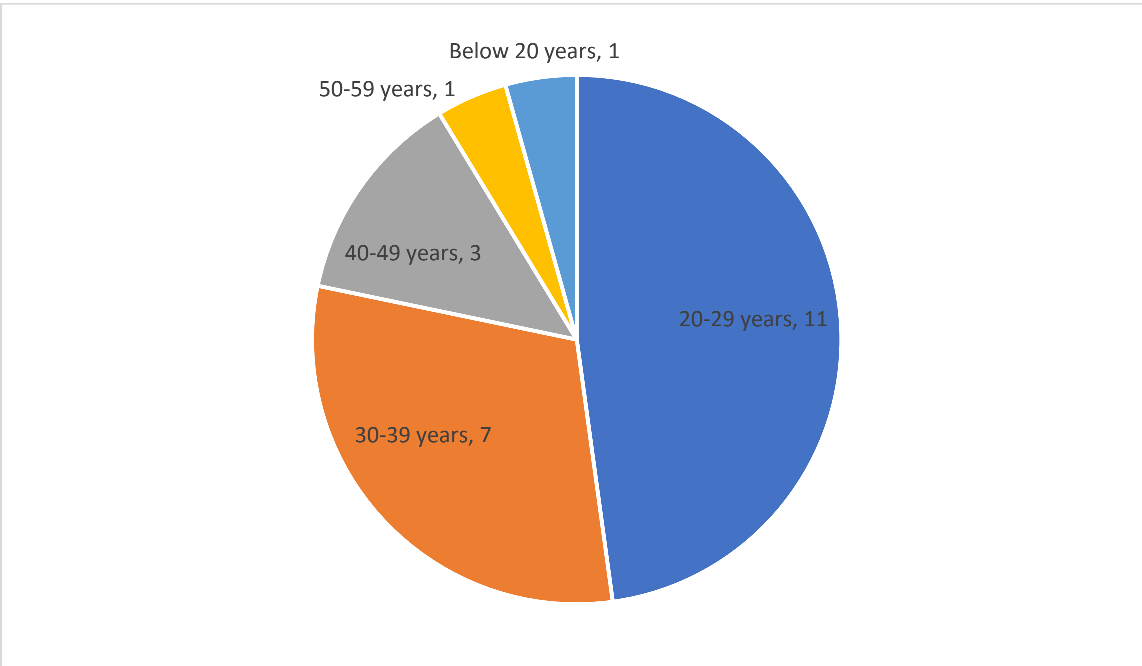

Figure 1 Age of household adopters

Figure 2 shows that 17 household adopters were males whereas 6 household adopters were females. Both gender were included.

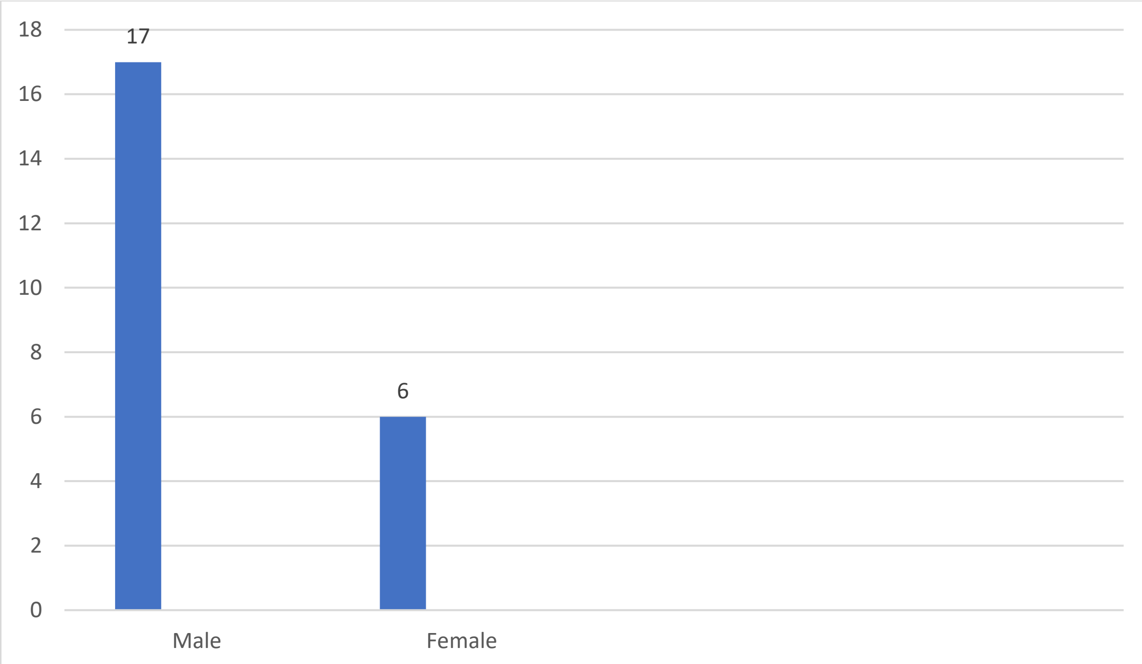

Figure 2 Gender of household adopters

5.2 Descriptive statistics

5.2.1 The level of knowledge and perception of households about the use of biogas technology

Table 1 shows that the price of biogas technology installation is greater had a higher mean factor of 4.52 among the other items. This means that the price of biogas technology installation is greater. The average score's divergence from the mean, or standard deviation, was 0.994, which reflects how broadly the distribution was dispersed. Training linked to biogas technology is difficult to get access to had the second mean factor of 4.17 among the other items. This means that training linked to biogas technology is difficult to get access to. The average score's divergence from the mean, or standard deviation, was 1.029, which reflects how broadly the distribution was dispersed. The advantages of biogas energy are not widely known had the third mean factor of 3.87 among the other items. This means that the advantages of biogas energy are not widely known. The average score's divergence from the mean, or standard deviation, was 1.140, which reflects how broadly the distribution was dispersed. The family is reluctant to the use of biogas technology had the fourth mean factor of 3.70 among the other items. This means that the family is reluctant to the use of biogas technology. The average score's divergence from the mean, or standard deviation, was 1.222, which reflects how broadly the distribution was dispersed.

The ability to obtain credit is challenging had the fifth mean factor of 3.48 among the other items. This means that the ability to obtain credit is challenging. The average score's divergence from the mean, or standard deviation, was 1.238, which reflects how broadly the distribution was dispersed. Time saved by biogas can be used for other tasks that generate cash had the sixth mean factor of 3.35 among the other items. This means that time saved by biogas can be used for other tasks that generate cash. The average score's divergence from the mean, or standard deviation, was 1.229, which reflects how broadly the distribution was dispersed. Having a sufficient and dependable water source is challenging had the sixth mean factor of 3.35 among the other items. This means that having a sufficient and dependable water source is challenging. The average score's divergence from the mean, or standard deviation, was 1.402, which reflects how broadly the distribution was dispersed. Water supplies are insufficient and unreliable had the sixth mean factor of 3.35 among the other items. This means that water supplies are insufficient and unreliable. The average score's divergence from the mean, or standard deviation, was 1.335, which reflects how broadly the distribution was dispersed.

Crop yields are directly increased by biogas had the ninth mean factor of 3.26 among the other items. This means that crop yields are directly increased by biogas. The average score's divergence from the mean, or standard deviation, was 1.356, which reflects how broadly the distribution was dispersed. There are not many livestock had the last mean factor of 3.09 among the other items. This means that there are not many livestock. The average score's divergence from the mean, or standard deviation, was 1.411, which reflects how broadly the distribution was dispersed.

Table 1 Descriptive Statistics for the level of knowledge and perception of households about the use of biogas technology

	Mean	Std. Deviation
The price of biogas technology installation is greater	4.52	.994
Training linked to biogas technology is difficult to get access to	4.17	1.029
The advantages of biogas energy are not widely known	3.87	1.140
The family is reluctant to the use of biogas technology	3.70	1.222
The ability to obtain credit is challenging	3.48	1.238
Time saved by biogas can be used for other tasks that generate cash	3.35	1.229
Having a sufficient and dependable water source is challenging	3.35	1.402
Water supplies are insufficient and unreliable	3.35	1.335
Crop yields are directly increased by biogas	3.26	1.356
There are not many livestock	3.09	1.411

5.2.2 Whether factors influencing household decisions on adoption and use of biogas technology have any effect on socio-economic, health, environment and climate aspects and identify the main challengers hindering the adoption of biogas technology

Table 2 shows that political backing and targeted initiatives to advance biogas technologies are lacking had a higher mean factor of 4.61 among the other items. This means that political backing and targeted initiatives to advance biogas technologies are lacking. The average score's divergence from the mean, or standard deviation, was 0.583, which reflects how broadly the distribution was dispersed. Lack of knowledge and minimal communication with potential adopters had second mean factor of 4.57 among the other items. This means that lack of knowledge and minimal communication with potential adopters. The average score's divergence from the mean, or standard deviation, was 0.590, which reflects how broadly the distribution was dispersed. Lack of understanding among the populace as a whole had third mean factor of 4.52 among the other items. This means that lack of understanding among the populace as a whole. The average score's divergence from the mean, or standard deviation, was 0.790, which reflects how broadly the distribution was dispersed.

Lack of consumer interest and public participation had fourth mean factor of 4.48 among the other items. This means that lack of consumer interest and public participation. The average score's divergence from the mean, or standard deviation, was 0.665, which reflects how broadly the distribution was dispersed. Adoption of biogas technologies is hampered by low literacy rates had fourth mean factor of 4.48 among the other items. This means that adoption of biogas technologies is hampered by low literacy rates. The average score's divergence from the mean, or standard deviation, was 0.665, which reflects how broadly the distribution was dispersed. Adoption is still going slowly had sixth mean factor of 4.35 among the other items. This means that adoption is still going slowly. The average score's divergence from the mean, or standard deviation, was 0.982, which reflects how broadly the distribution was dispersed. Lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas had sixth mean factor of 4.35 among the other items. This means that lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas. The average score's divergence from the mean, or standard deviation, was 0.775, which reflects how broadly the distribution was dispersed.

Installations of biogas entail significant financial outlays had eighth mean factor of 4.17 among the other items. This means that installations of biogas entail significant financial outlays. The average score's divergence from the mean, or standard deviation, was 0.984, which reflects how broadly the distribution was dispersed. There are not enough resources had eighth mean factor of 4.17 among the other items. This means that there are not enough resources. The average score's divergence from the mean, or standard deviation, was 1.114, which reflects how broadly the distribution was dispersed. There is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized had tenth mean factor of 4.13 among the other items. This means that there is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized. The average score's divergence from the mean, or standard deviation, was 1.014, which reflects how broadly the distribution was dispersed.

The expensive management and upkeep of biogas plants had tenth mean factor of 4.13 among the other items. This means that the expensive management and upkeep of biogas plants. The average score's divergence from the mean, or standard deviation, was 0.757, which reflects how broadly the distribution was dispersed. Travel expenses and erratic supplies had twelfth mean factor of 4.04 among the other items. This means that travel expenses and erratic supplies. The average score's divergence from the mean, or standard deviation, was 0.767, which reflects how broadly the distribution was dispersed. There are not enough subsidies had thirteenth mean factor of 3.91 among the other items. This means that there are not enough subsidies. The average score's divergence from the mean, or standard deviation, was 1.164, which reflects how broadly the distribution was dispersed. The infrastructure is subpar had fourteenth mean factor of 3.87 among the other items. This means that the infrastructure is subpar. The average score's divergence from the mean, or standard deviation, was 0.869, which reflects how broadly the distribution was dispersed.

Biogas digesters require a lot of water resources had fifteenth mean factor of 3.74 among the other items. This means that biogas digesters require a lot of water resources. The average score's divergence from the mean, or standard deviation, was 0.915, which reflects how broadly the distribution was dispersed. Projects involving biogas fail because they conflict with local beliefs had sixteenth mean factor of 3.48 among the other items. This means that projects involving biogas fail because they conflict with local beliefs. The average score's divergence from the mean, or standard deviation, was 1.123, which reflects how broadly the distribution was dispersed. Higher pricing for biogas and lower prices for fossil fuels had seventeenth mean factor of 3.35 among the other items. This means that higher pricing for biogas and lower prices for fossil fuels is a challenge hindering the adoption of biogas technology. The average score's divergence from the mean, or standard deviation, was 1.265, which reflects how broadly the distribution was dispersed.

Concerns about odor had eighteenth mean factor of 3.17 among the other items. This means that concerns about odor is a challenge hindering the adoption of biogas technology. The average score's divergence from the mean, or standard deviation, was 1.642, which reflects how broadly the distribution was dispersed. Noise toxicity had the last mean factor of 2.87 among the other items. This means that noise toxicity is a challenge hindering the adoption of biogas technology. The average score's divergence from the mean, or standard deviation, was 1.456, which reflects how broadly the distribution was dispersed.

Table 2 Descriptive Statistics for whether factors influencing household decisions on adoption and use of biogas technology have any effect on socio-economic, health, environment and climate aspects and identify the main challengers hindering the adoption of biogas technology

	Mean	Std. Deviation
Political backing and targeted initiatives to advance biogas technologies are lacking	4.61	.583
Lack of knowledge and minimal communication with potential adopters	4.57	.590
Lack of understanding among the populace as a whole	4.52	.790
Lack of consumer interest and public participation	4.48	.665
Adoption of biogas technologies is hampered by low literacy rates	4.48	.665
Adoption is still going slowly	4.35	.982
Lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas	4.35	.775
Installations of biogas entail significant financial outlays	4.17	.984
There are not enough resources	4.17	1.114
There is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized	4.13	1.014
The expensive management and upkeep of biogas plants	4.13	.757
Travel expenses and erratic supplies	4.04	.767
There are not enough subsidies	3.91	1.164
The infrastructure is subpar	3.87	.869
Biogas digesters require a lot of water resources	3.74	.915
Projects involving biogas fail because they conflict with local beliefs	3.48	1.123
Higher pricing for biogas and lower prices for fossil fuels	3.35	1.265
Concerns about odor	3.17	1.642
Noise toxicity	2.87	1.456

5.2.3 The approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure

Table 3 shows that for the best biogas production, use feedstocks with the right C/N ratio had a higher mean factor of 4.35 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is for the best biogas production, household adopters must use feedstocks with the right C/N ratio. The average score's divergence from the mean, or standard deviation, was 0.885, which reflects how broadly the distribution was dispersed. Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove had a higher mean factor of 4.35 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove. The average score's divergence from the mean, or standard deviation, was 0.885, which reflects how broadly the distribution was dispersed. To make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook had third mean factor of 4.30 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook. The average score's divergence from the mean, or standard deviation, was 0.926, which reflects how broadly the distribution was dispersed.

The central manhole cover lid or the expansion chamber would need to be opened for an inspection had fourth mean factor of 4.26 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is, the central manhole cover lid or the expansion chamber would need to be opened for an inspection. The average score's divergence from the mean, or standard deviation, was 1.054, which reflects how broadly the distribution was dispersed. The operator should monitor any temperature changes that occur during the anaerobic digestion process had fifth mean factor of 4.22 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is, the operator should monitor any temperature changes that occur during the anaerobic digestion process. The average score's divergence from the mean, or standard deviation, was 0.951, which reflects how broadly the distribution was dispersed. The operator should be aware of the digester's mixing, temperature changes, and uneven supply if there is foam had sixth mean factor of 4.17 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is, the operator should be aware of the digester's mixing, temperature changes, and uneven supply if there is foam. The average score's divergence from the mean, or standard deviation, was 0.984, which reflects how broadly the distribution was dispersed.

Utilize a premium brick stacking standard when building had seventh mean factor of 4.13 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to utilize a premium brick stacking standard when building. The average score's divergence from the mean, or standard deviation, was 1.014, which reflects how broadly the distribution was dispersed. Ensure that the sodium concentration stays between 3500 and 5500 parts per million, according to the operator (ppm) had eighth mean factor of 4.09 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to ensure that the sodium concentration stays between 3500 and 5500 parts per million, according to the operator (ppm). The average score's divergence from the mean, or standard deviation, was 0.848, which reflects how broadly the distribution was dispersed. The operator must ensure that the soluble heavy metal content is kept to less than 0.5 mg/L had ninth mean factor of 4.04 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is, the operator must ensure that the soluble heavy metal content is kept to less than 0.5 mg/L. The average score's divergence from the mean, or standard deviation, was 0.928, which reflects how broadly the distribution was dispersed.

Verify the flame's color at the waste gas burner had tenth mean factor of 3.96 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to verify the flame's color at the waste gas burner. The average score's divergence from the mean, or standard deviation, was 0.928, which reflects how broadly the distribution was dispersed. To prevent harm to the biodigester system, volatile fatty acid concentrations should be fewer than 2000 parts per million (ppm) had eleventh mean factor of 3.91 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to prevent harm to the biodigester system, volatile fatty acid concentrations should be fewer than 2000 parts per million (ppm). The average score's divergence from the mean, or standard deviation, was 0.848, which reflects how broadly the distribution was dispersed. To prevent digestion failure in the biogas plant, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L had the last mean factor of 3.87 among the other items. This means that an approach used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure is to prevent digestion failure in the biogas plant, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L. The average score's divergence from the mean, or standard deviation, was 1.140, which reflects how broadly the distribution was dispersed.

Table 3 Descriptive Statistics the approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure

	Mean	Std. Deviation
For the best biogas production, use feedstocks with the right C/N ratio	4.35	.885
Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove	4.35	.885
To make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook	4.30	.926
The central manhole cover lid or the expansion chamber would need to be opened for an inspection	4.26	1.054
The operator should monitor any temperature changes that occur during the anaerobic digestion process	4.22	.951
The operator should be aware of the digester's mixing, temperature changes, and uneven supply if there is foam	4.17	.984
Utilize a premium brick stacking standard when building	4.13	1.014
Ensure that the sodium concentration stays between 3500 and 5500 parts per million, according to the operator (ppm)	4.09	.848
The operator must ensure that the soluble heavy metal content is kept to less than 0.5 mg/L	4.04	.928
Verify the flame's color at the waste gas burner	3.96	.928
To prevent harm to the biodigester system, volatile fatty acid concentrations should be fewer than 2000 parts per million (ppm)	3.91	.848

To prevent digestion failure in the biogas plant, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L	3.87	1.140

5.3 Discussion of findings

5.3.1 The level of knowledge and perception of households about the use of biogas technology

Approximately 35 billion m^3 of equivalent methane - or 59 billion m^3 of biogas - are produced globally each year, with the European Union (EU) contributing approximately half of that amount (Norouzi & Dutta, 2022). As a result, biogas production in developing nations has been inadequate and has made little progress. In terms of biogas production, developing nations lag behind their developed counterparts. Due to varying socioeconomic situations, technological advancements, degrees of development, and endowments of natural resources, the deployment of biogas in developing countries differs substantially between nations (Zupančič et al., 2022). China has the most household biogas plants in the world (Igliski et al., 2020), and small-scale domestic biogas plants are widely implemented in these countries (Nevzorova, 2020). However, by building medium- and large-scale biogas facilities, most emerging nations are increasing their pace of growth to grow their biogas production. Findings of this study revealed that household adopters strongly agreed that the price of biogas technology installation is greater, training linked to biogas technology is difficult to get access to and the advantages of biogas energy are not widely known.

Findings also showed that the family is reluctant to the use of biogas technology, the ability to obtain credit is challenging, and time saved by biogas can be used for other tasks that generate cash. Moreover, having a sufficient and dependable water source is challenging, water supplies are insufficient and unreliable, crop yields are directly increased by biogas, and there are not many livestock. An issue to consider is water availability, as this puts irrigation water and drinking water in competition (SABIA 2016). However, several studies have investigated the accessibility of grey water (Nape et al. 2019). Furthermore, according to Von Bormann and Gulati (2014), the amount of water required to produce power is expected to increase. Water allocation trade-offs between energy and agriculture will be difficult in this regard. The African Biogas Partnership Programme brought biogas technology to the continent. In Burundi, Botswana, Burkina Faso, Cote d'Ivoire, Ethiopia, Ghana, Guinea, Lesotho, Namibia, Nigeria, Rwanda, Zimbabwe, South Africa and Uganda, several biogas digesters have been installed (Clemens et al., 2018).

According to estimates, Nigeria, the most populous nation in Africa, has a biogas potential of 6.8 million cubic metres per day from animal manure and 913,440 tons of methane from MSW, which is equal to 482 MW of electricity [44]. By 2030, Nigeria is expected to produce 171 TJ of biogas energy (Yimen et al., 2018). Despite the promise of biogas in African nations and the viability of the technology having been demonstrated by various programmes, the technology is not widely used and large-scale applications have not been successfully implemented (Kemausuor et al., 2018; Dumont et al., 2021).

5.3.2 Whether factors influencing household decisions on adoption and use of biogas technology have any effect on socio-economic, health, environment and climate aspects and identify the main challengers hindering the adoption of biogas technology

Findings revealed that political backing and targeted initiatives to advance biogas technologies are lacking, there is lack of knowledge and minimal communication with potential adopters, there is lack of understanding among the populace as a whole, and there is lack of consumer interest and public participation. Moreover, adoption of biogas technologies is hampered by low literacy rates, adoption is still going slowly, lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas, installations of biogas entail significant financial outlays, there are not enough resources, and there is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized. Although some developing nations, such as China, India, and Nepal, have successfully adopted biogas (see Bond and Templeton 2011), this has not been the case in many other nations where the digesters are not working. This is because there aren't enough maintenance resources available, and the facilities that already exist aren't getting fixed. South Africa has also experienced this.

For example, SABIA (2016) noted that the energy sector faces serious challenges due to a lack of qualified local labour and skilled manpower, as the system frequently relies on foreign nationals from wealthy countries to run the facilities. Furthermore, there is expensive management and upkeep of biogas plants, there is travel expenses and erratic supplies, there are not enough subsidies, the infrastructure is subpar, biogas digesters require a lot of water resources, and projects involving biogas fail because they conflict with local beliefs. Lastly, higher pricing for biogas and lower prices for fossil fuels, concerns about odor, and noise toxicity are challenges hindering the adoption of biogas technology. In poor countries, it might be challenging to locate a grid connected to a large-scale biogas programme. Furthermore, the inability of rural farmers to invest in biogas facilities is a barrier to their progress (Wargert 2009). Furthermore, underground methane digesters that are installed are inundated during the rainy season, according to Wargert (2009), which requires a significant amount of maintenance effort and expense.

This is related to the construction of methane digesters using unsuitable forms and materials (Mutungwazi, Mukumba and Makaka 2018). According to Taele, Gopinathan, and Mokhutsoane (2007), the seasonal movement of livestock in rural regions makes it challenging to collect enough animal waste to feed biogas digesters and causes a sizable interruption in generation capacity. A large-scale farming system makes it challenging to gather animal faeces, according to Wargert (2009). According to Nape et al. (2019), due to the cold winter months, the methane digesters built in rural communities do not produce enough biogas.

5.3.3 The approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure

Findings revealed that the approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure are for the best biogas production, household adopters must use feedstocks with the right C/N ratio; Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove; to make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook; the central manhole cover lid or the expansion chamber would need to be opened for an inspection; the operator should monitor any temperature changes that occur during the anaerobic digestion process; the operator should be aware of the digester's mixing, temperature changes, and uneven supply if there is foam; utilize a premium brick stacking standard when building; ensure that the sodium concentration stays between 3500 and 5500 parts per million, according to the operator (ppm); the operator must ensure that the soluble heavy metal content is kept to less than 0.5 mg/L; verify the flame's color at the waste gas burner; to prevent harm to the biodigester system; volatile fatty acid concentrations should be fewer than 2000 parts per million (ppm); and to prevent digestion failure in the biogas plant, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L.

Developing nations must create their own, more affordable digestion systems with simple installation and operation methods. It is important to streamline technical services and biodigester management so that people can buy high-quality energy at a reasonable price (Xue et al., 2020). Conversion procedures should also be made simpler to cut costs associated with production. It is important to promote international collaboration and the exchange of best practises. Additionally, steps must be taken to improve the management of biogas plants and follow-up services (Mateescu & Dima, 2020). Without adequate education, this is not possible. For considerable changes, funding from non-governmental organizations and the government is required. Many years of central government funding through local investment programmes (LIP) and climate investment programmes (KLIMP) have allowed considerable advances in the use of biogas for energy generation and automobile fuel in countries like Sweden, Denmark, and Germany.

In order to make Vester Hjermitslev in Denmark energy self-sufficient, the first plant was built there with almost all public funding: a 4 million DKK grant from the government and an 8.4 million DKK loan from the North Jutland County Council (Chrispim et al., 2021). Additionally, there are loan programmes with low long-term interest rates and investment subsidies for centralised biogas facilities that can cover up to 40% of expenditures. Another viable alternative to support biogas implementation in developing countries is carbon trading through Voluntary Emission Reduction (VER) managed by the World Bank (Güsewell et al., 2019; Karlsson, 2019).

Policies are required to encourage the production of biogas for the generation of electricity in developing countries. In wealthy nations, policies such as feed-in tariffs, net metering, virtual net metering, and tax incentives have greatly aided the development of renewable energy sources (Tabatabaei et al., 2020). Tax exemptions or reductions on fossil fuels and rules requiring filling stations to offer at least one renewable fuel are among the policies in Sweden that favour renewable transportation fuel (Kiselev & Magaril, 2022).

6. CONCLUSIONS

The main aim of the current study was to investigate the factors influencing household decisions on the adoption and use of biogas technologies and the implementation benefits in terms of the socio-economic, environmental, health and climate issues in relation among households in rural areas of the Offinso North district in the Ashanti region of Ghana. The research design for the current study was quantitative with surveys using questionnaires to obtain the opinions of the respondents to formulate the research findings. To achieve the objective of this study, explanatory and descriptive research methods were employed. The research focused on rural households in the offinso North (Ashanti region) in Ghana, and stakeholders in government and non-government institutions. The sample size was determined based on the number of adopters of the household and who were willing to respond to the questionnaire in the Offinso North District. Convenient sampling technique was employed. It was found that household adopters strongly agreed that the price of biogas technology installation is greater, training related to biogas technology is difficult to access, and the advantages of biogas energy are not widely known.

The findings also showed that the family is reluctant to use biogas technology, the ability to obtain credit is challenging, and the time saved by biogas can be used for other tasks that generate cash. Furthermore, having a reliable and sufficient water source is challenging, water supplies are insufficient and unreliable, crop yields are directly increased by biogas, and there are few livestock. It was also found that political backing and targeted initiatives to advance biogas technologies are lacking, there is lack of knowledge and minimal communication with potential adopters, there is lack of understanding among the populace as a whole, there is lack of consumer interest and public participation, adoption of biogas technologies is hampered by low literacy rates, adoption is still going slowly, lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas, installations of biogas entail significant financial outlays, there are not enough resources, and there is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized.

Lastly, it was found that for the best biogas production, household adopters must use feedstocks with the right C/N ratio, Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove, and to make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook are some approaches used by the government and NGOs in the development, design, and implementation of biogas technology in order to establish the causes of the system failure.

6.1 Recommendation

People need to be aware of the value of properly managing the wastes they produce on a daily basis and the advantages of the biogas they can produce. Continuous counseling and teaching are needed on proper waste management, trash reduction, reuse for a longer period of time, recycling to create new products and recovery of waste energy in communities, schools, and market places. Governments should encourage research and development (R&D) by making sure that universities and businesses in emerging nations work closely together. The fact that imported technology does not align with regional needs and accessible infrastructure is a significant barrier to the development of biogas plants. R&D is therefore required to create new regional technologies or to alter those that already exist. Universities can carry out pilot projects to assess the viability of the technology and create the best conditions for a successful adoption. After that, companies can use the technology.

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APPENDIX A

QUESTIONNAIRE

Dear respondent, this questionnaire is designed to gather data about the influencing factors for household decisions on adoption and use biogas technologies and the implementation benefits in terms of the socio-economic, environmental, health and climate issues in relation among households in the rural areas of Offinso North district in the Ashanti region of Ghana. Your kind cooperation in this research is very much appreciated. Your anonymity and confidentiality are assured.

SECTION A: YOUR PERSONAL DATA

Please indicate your response to statements by ticking [√] the appropriate box.

1. Age: Below 20 years [ ] 20-29 years [ ] 30-39 years [ ] 40-49 years [ ] 50-59 years [ ] 60 years or above [ ]

2. Gender: Male [ ] Female [ ]

THE LEVEL OF KNOWLEDGE AND PERCEPTION OF HOUSEHOLDS ON THE USE OF BIOGAS TECHNOLOGY

This category contains statements about the level of knowledge and perception of households on the use of biogas technology. Please indicate your level of agreement to the statements using the 5-point Likert scale below by ticking [√] the appropriate box:

1= Strongly disagree 2= Disagree 3= Undecided 4= Agree 5 = Strongly agree

S/N	Statement	1	2	3	4	5
1.	The advantages of biogas energy are not widely known					
2.	The family is reluctant to the use of biogas technology					
3.	The price of biogas technology installation is greater					
4.	There are not many livestock					
5.	Water supplies are insufficient and unreliable					
6.	Having a sufficient and dependable water source is challenging					
7.	The ability to obtain credit is challenging					
8.	Training linked to biogas technology is difficult to get access to					
9.	Crop yields are directly increased by biogas					
10.	Time saved by biogas can be used for other tasks that generate cash					

WHETHER INFLUENCING FACTORS FOR HOUSEHOLD DECISIONS ON ADOPTION AND USE OF BIOGAS TECHNOLOGY HAS ANY EFFECT ON THE SOCIO-ECONOMIC, HEALTH, ENVIRONMENT AND CLIMATE ASPECTS AND IDENTIFY THE MAJOR CHALLENGES HINDERING THE ADOPTION OF THE BIOGAS TECHNOLOGY

This category contains statements about whether influencing factors for household decisions on adoption and use of biogas technology has any effect on the socio-economic, health, environment and climate aspects and identify the major challenges hindering the adoption of the biogas technology. Please indicate your level of agreement to the statements using the 5-point Likert scale below by ticking [√] the appropriate box:

1= Strongly disagree 2= Disagree 3= Undecided 4= Agree 5 = Strongly agree

S/N	Statement	1	2	3	4	5
1.	Adoption is still going slowly					
2.	There are not enough resources					
3.	The infrastructure is subpar					
4.	Travel expenses and erratic supplies					
5.	Installations of biogas entail significant financial outlays					
6.	The expensive management and upkeep of biogas plants					
7.	There aren't enough subsidies					
8.	Higher pricing for biogas and lower prices for fossil fuels					
9.	Political backing and targeted initiatives to advance biogas technologies are lacking					
10.	Lack of private sector involvement and ineffective public-private sector collaboration are obstacles to the uptake of biogas					
11.	Lack of consumer interest and public participation					
12.	Projects involving biogas fail because they conflict with local beliefs					
13.	Lack of understanding among the populace as a whole					
14.	Lack of knowledge and minimal communication with potential adopters					
15.	Adoption of biogas technologies is hampered by low literacy rates					
16.	There is difficulty to switch from old technology that is free to a stove that has upfront expenses, and other demands are prioritized					
17.	Noise toxicity					
18.	Concerns about odor					
19.	Biogas digesters require a lot of water resources					

THE APPROACHES USED BY THE GOVERNMENT AND NGOS IN THE DEVELOPMENT, DESIGNING AND IMPLEMENTATION OF BIOGAS TECHNOLOGY IN-ORDER TO ESTABLISH THE CAUSES OF THE SYSTEM FAILURE

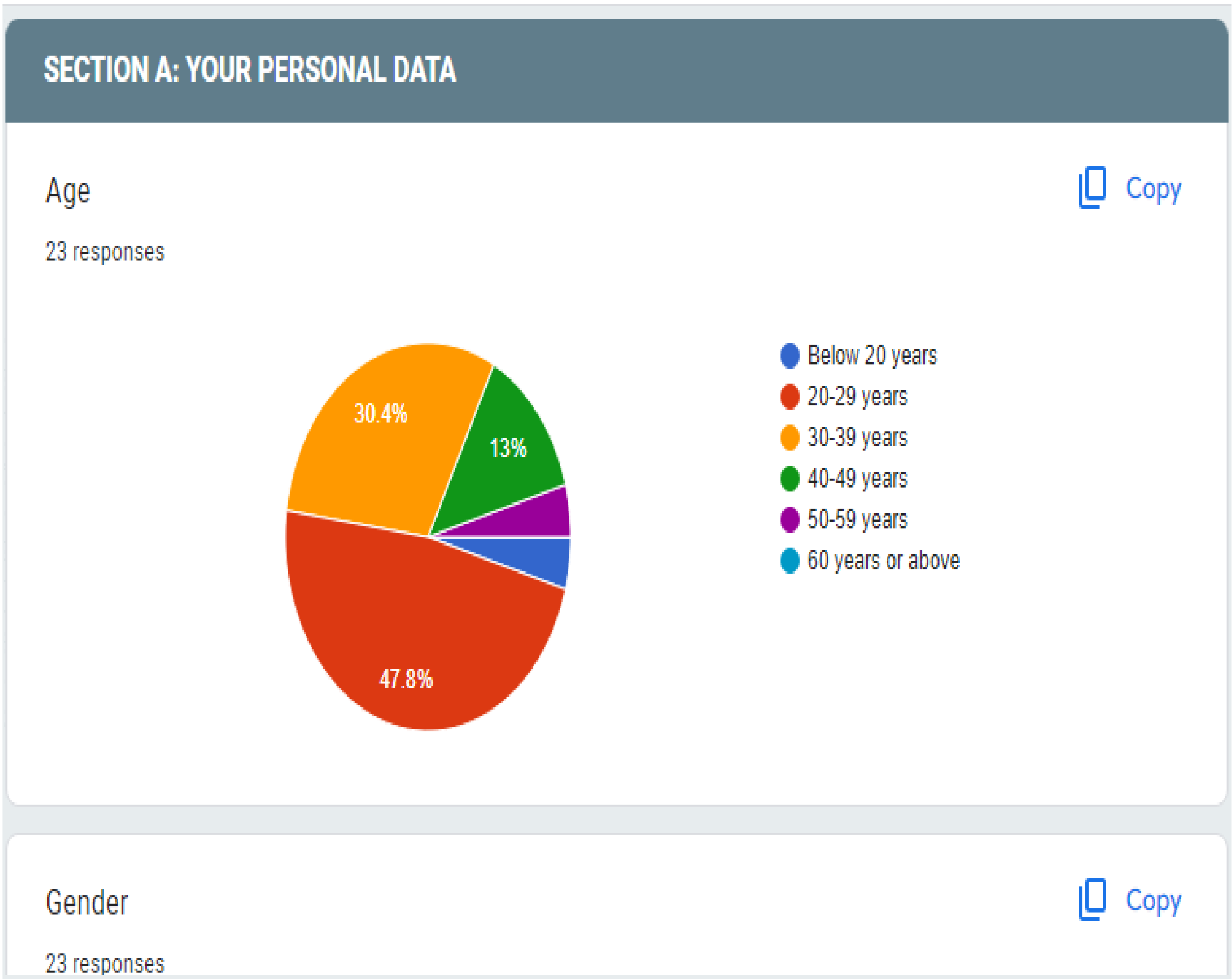
This category contains statements about the approaches used by the government and NGOs in the development, designing and implementation of biogas technology in-order to establish the causes of the system failure. Please indicate your level of agreement to the statements using the 5-point Likert scale below by ticking [√] the appropriate box:

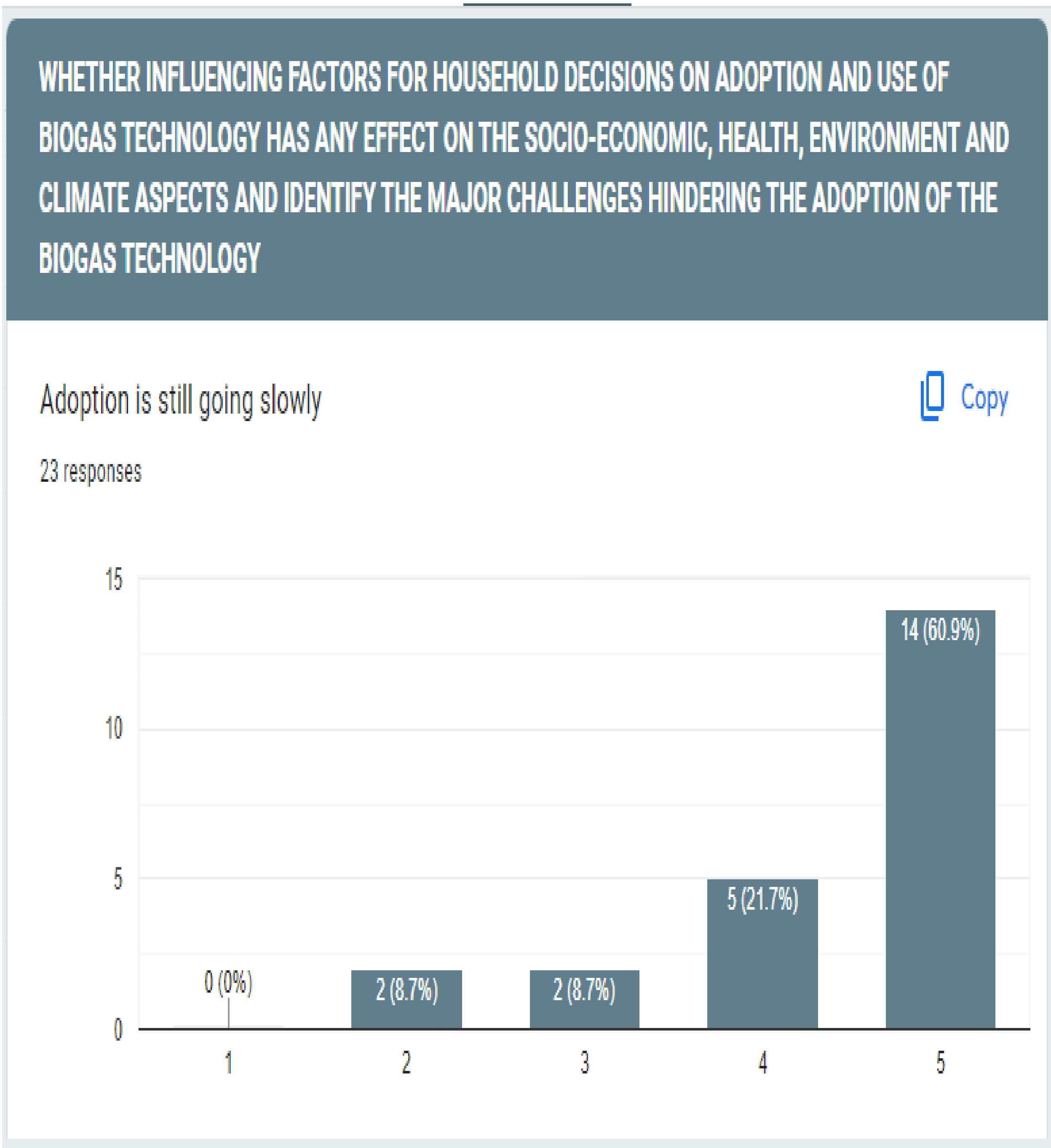
1= Strongly disagree 2= Disagree 3= Undecided 4= Agree 5 = Strongly agree

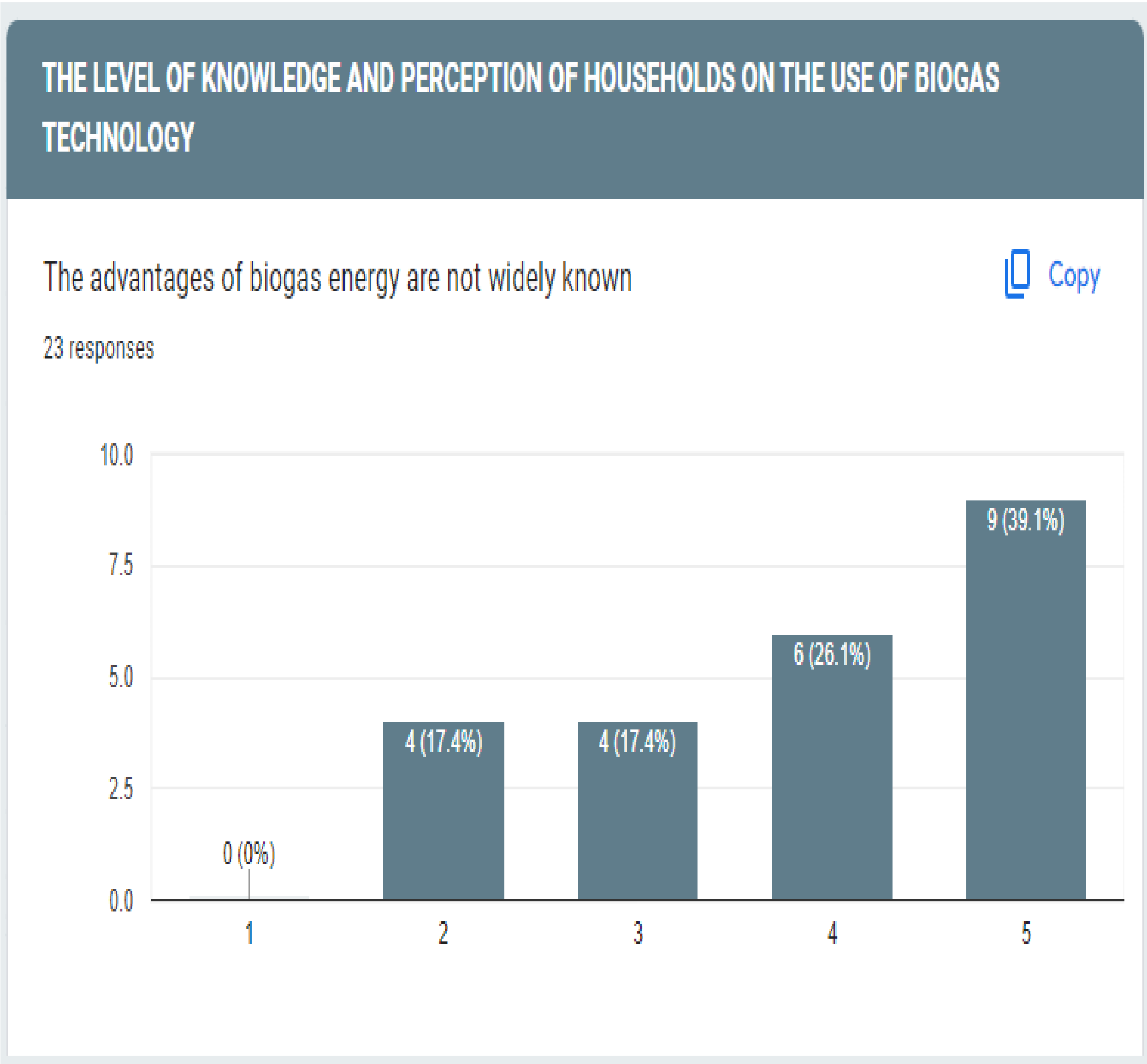
S/N	Statement	1	2	3	4	5
1.	The central manhole cover lid or the expansion chamber would need to be opened for an inspection					
2.	Utilize a premium brick stacking standard when building					
3.	For the best biogas production, use feedstocks with the right C/N ratio					
4.	To make sure the biodigester is correctly fed, make sure it gets the right amount of feed each day and check the feeding logbook					
5.	To prevent digestion failure in the biogas plant, the operator should keep the ammonia content below 2000 ppm, or between 50 and 200 mg/L					
6.	To prevent harm to the biodigester system, volatile fatty acid concentrations should be fewer than 2000 parts per million (ppm)					
7.	Verify the flame's color at the waste gas burner					
8.	Ensure that the sodium concentration stays between 3500 and 5500 parts per million, according to the operator (ppm)					
9.	The operator must ensure that the soluble heavy metal content is kept to less than 0.5 mg/L					
10.	The operator should monitor any temperature changes that occur during the anaerobic digestion process					
11.	The operator should be aware of the digester's mixing, temperature changes, and uneven supply if there is foam					
12.	Struvite deposits in the digesters should be monitored by the operator because they are challenging to remove					

APPENDIX B

DATA COLLECTION PICTURES




WHETHER INFLUENCING FACTORS FOR HOUSEHOLD DECISIONS ON ADOPTION AND USE OF BIOGAS TECHNOLOGY HAS ANY EFFECT ON THE SOCIO-ECONOMIC, HEALTH, ENVIRONMENT AND CLIMATE ASPECTS AND IDENTIFY THE MAJOR CHALLENGES HINDERING THE ADOPTION OF THE BIOGAS TECHNOLOGY
Adoption is still going slowly
Copy
23 responses
15
10
5
0
0 (0%)
2 (8.7%)
2 (8.7%)
5 (21.7%)
14 (60.9%)
1
2
3
4
5


THE LEVEL OF KNOWLEDGE AND PERCEPTION OF HOUSEHOLDS ON THE USE OF BIOGAS TECHNOLOGY
The advantages of biogas energy are not widely known
Copy
23 responses
10.0
7.5
5.0
2.5
0.0
0 (0%)
4 (17.4%)
4 (17.4%)
6 (26.1%)
9 (39.1%)
1
2
3
4
5

THE APPROACHES USED BY THE GOVERNMENT AND NGOS IN THE DEVELOPMENT, DESIGNING AND IMPLEMENTATION OF BIOGAS TECHNOLOGY IN-ORDER TO ESTABLISH THE CAUSES OF THE SYSTEM FAILURE

The central manhole cover lid or the expansion chamber would need to be opened for an inspection

Copy

23 responses