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Faculty of Tropical AgriSciences

# Influencing factors for household decisions on use and adoption of biogas technology: The case of Bamenda, Northwest Region of Cameroon

MASTER'S THESIS

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**Declaration**

I hereby declare that I have done this thesis entitled "Influencing Factors on Household Use and Adoption of Biogas Technology: The Case of Bamenda, Northwest Region of Cameroon", independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, April 24, 2024

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Ayeah Gideon Gobti, BSc.

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**Abstract**

Nowadays, research on renewable energy sources is increasingly gaining global attention because of the devastating consequences of non-renewable energy on the environment. Consequently, work on adopting biogas technology has been in the limelight. This is of special concern for developing countries due to the low level of adoption despite abundant resources. In Cameroon, the adoption rate of biogas technology is very low despite abundant resources and awareness available. Therefore, this study focuses on finding out the influencing factors for household decisions to adopt and use biogas technology in Bamenda, Northwest Cameroon. Self-administered questionnaires, semi-structured questionnaires, and interviews were used to collect quantitative and qualitative primary data from 129 respondents of which 112 were non-biogas users and 17 were biogas users. Descriptive statistics showed that females had a significant proportion of 51.2% and households averaging six members was 28.7%, with 58.1% of respondents having access to loans, while 62.8% owned land. Biogas technology in Bamenda, Cameroon, is in its early stages, with few farmers and non-farmers adopting small-scale household plants, mainly fueled by human or animal waste. These plants, constructed with local materials, primarily support cooking needs, while larger-scale installations serve institutions like hospitals and schools. With the multiple logit regression analysis, it was found that two variables: loan access ($P = 0.05$) and land ownership ($P = 0.02$) out of 14 variables had statistical significance with a negative impact on household decisions about use and adoption of biogas technology, while 12 had no significant effect ($P > 0.05$). These findings will serve as groundwork for further studies, and we recommend that more research be carried out in this area with a focus on biogas users and farmers emphasising the political, cultural, and technological factors and using other proper methodological approaches.

**Keywords**: Renewable energy, biogas users, farmers, environment, awareness

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**List of abbreviations**

GHG: Greenhouse gases

SSA: Sub-Saharan Africa

GDP: Gross Domestic Product

NGOs: Non-Governmental Organisations

SNV: Netherlands Development Organisation

SHUMAS: Strategic Humanitarian Services

HYSACAM: Cameroonian Society of Hygiene and Sanitation

AD: Anaerobic Digestion

HRT: Hydraulic Retention Time

pH: Potential of Hydrogen

GW: Global Warming

GWP: Global Warming Potential

BGT: Biogas Technology

UN: United Nations

SDGs: Sustainable Development Goals

LPG: Liquified Petroleum Gas

VF: Variance Factor

HH: Households

MW: Mega Watt

KgVS/$m^3$: kilograms of volatile solids per cubic met

# 1 Introduction

## 1.1 Background

Energy is one of the most indispensable commodities in our society, as all sectors depend on it for its survival (Paul & Ameh 2017). It is a determinant driver of poverty reduction, and socioeconomic, and sustainable development (Khan & Martin 2016). As a result, its high demand due to rapid population growth and industrialisation leads to constant price fluctuations World Bank (2024), not leaving out its adverse effect on health and the environment (Hassan et al. 2021). Currently, fossil energy, the main energy source, remains the most widely used energy in many sectors, which is responsible for the emission of greenhouse gases (GHG) that cause global warming (Muh et al. 2018a). This has led to the search for alternative, innovative, cheap, clean, and sustainable sources of energy, such as biogas, among others (Mensah et al. 2021). Therefore, the widespread use of biogas technology at the household level has been adopted in numerous developing countries (Roubik 2018a).

In Africa, despite abundant sources of energy, there are still some disparities in energy distribution, where around 70% of the continent depends on imported energy (Muh et al. 2018). This energy gap has led to a setback in the rapid industrialisation and sustainable development of Africa (Okudoh et al. 2014). It is estimated that in Sub-Sahara Africa (SSA) and Asia-Pacific, approximately 2.7 billion people do not have access to clean cooking facilities (Zervos & Lins 2016). They depend on traditional biomass energy for their essential needs despite the health and environmental issues associated with it. This accounts for the high consumption of traditional biomass of approximately 70 - 95% of energy consumption in Africa, particularly in remote areas (Benti et al. 2021). Therefore, embracing renewable, clean, and affordable energy sources such as biogas technology will reduce dependence on traditional biomass energy consumption to a greater extent by producing sustainable energy and organic fertilisers for agricultural purposes (Mmusi et al. 2021).

Cameroon is a developing country located in central Africa with a population of about 30 million inhabitants. It is bounded to the west by Nigeria, to the north by Chad, to the east by the Central African Republic, and to the south by Gabon and Equatorial Guinea (Kolot et al. 2022). It is known for its cultural, geographical, and political diversity. The country is divided into 10 regions (Abanda 2012). Divided into five agroecological zones, its tropical climate favours the growth of a variety of crops, such as cereals, tubers, legumes, fruits, oil palm, and cocoa and coffee are among the main export crops (Nchuaji 2024).

Approximately 80% of the rural population depends on agriculture for a living and with other related activities, agriculture contributes about 35% of the national gross domestic product (GDP) (Molua et al. 2007). In the Northwest region, three divisions out of seven, namely Mezam, Boyo and Bui, practice biogas production (Ngala et al. 2020). Therefore, the area, which falls under the Mezam division, is ideal for the study. Biogas production was introduced in this region by the Cameroon Ministry of Water and Energy and the Netherlands Development Organisation (SNV) through the national domestic biogas programme (Roopnarain & Adeleke 2017). Other non-governmental international organisations (NGOs) such as Heifer and the Strategic Humanitarian Service (SHUMAS) have helped implement biogas technology in other regions of the country (Ngala et al. 2020). In 2010, 105 digesters were constructed, 206 digesters by 2013, and a plan to reach 1000 digesters by 2014 by SNV (Roopnarain & Adeleke 2017). Today, the number of digesters would have double or triple though an accurate number cannot be estimated due to lack of documentation.

Biogas technology is a process in which organic waste obtained from agricultural and forest residues, animal, and human manure, sewage sludge, and municipal waste is transformed into gas through anaerobic digestion (AD) by a chain of microbes using different systems (Bond & Templeton 2011; Achinas & Euverink 2016). Biogas consists of methane ($CH_4$) gas, carbon dioxide ($CO_2$) with trace elements such as $NH_3$, siloxanes, oxygen ($O_2$), nitrogen ($N_2$), hydrogen sulphide ($H_2S$) and hydrogen ($H_2$), depending on the substrate (Okudoh et al. 2014). It is used primarily for cooking and lighting in Africa (Tumwesige et al. 2014).

## 1.2 Problem Statement

Despite the awareness about biogas technology in Bamenda Cameroon, the number of people who have adopted and using the technology is very low. With abundant waste produced by households, most of them use fuelwood for cooking which is not economically and environmentally sustainable. Also, poor waste management is causing enormous amounts of environmental pollution. Therefore, it is important to find out the factors that determine the adoption and use of biogas in this area. According to Roubik (2018), “there is a need to facilitate the use of technology and make this technology more effective for end users in developing countries.” Little has been done in this area, as most of the work conducted focuses on the impacts, potential, opportunities, and sustainability of biogas technology. Therefore, there is a lack of adequate information on the factors that influence household decisions about the adoption and use of biogas technology in Bamenda, Cameroon, making this work of vital importance. The research will contribute to the existing body of knowledge on biogas technology and provide information to policymakers that will allow them to make informed decisions in the field of biogas technology.

# 2 Literature review

## 2.1 Theoretical framework

## 2.2 Biogas production technology

It is a biochemical process in which organic matter is broken down under anaerobic conditions (anaerobic digestion) with the help of microorganisms to liberate a gaseous mixture made rich in methane ($CH_4$) and carbon dioxide ($CO_2$) (Kadam & Panwar 2017). The composition and impurities of the end product, $CH_4$ and $CO_2$ called biogas, are determined by the type of substrate, climate, production site, and technology used (Kadam & Panwar 2017). The underlying principle, of anaerobic digestion is a process that occurs in the natural environment such as swamps and ruminant stomachs (Vögeli et al. 2014). The integrated process consists of substrate supply and pretreatment, anaerobic digestion, gas treatment, utilisation, recovery, pretreatment, and digestate use (Poeschl et al. 2010).

Research on microbial anaerobic digestion by scholars in the 1960s has led to the improvement of waste, in which solid waste and wastewater (industrial and municipal waste) are treated today (Muh et al. 2018b). It is the most suitable method for treating organic waste compared to aerobic digestion when talking about emissions (Muh et al. 2018b). It is also less costly than other methods of treatment such as landfills and incineration (Grando et al. 2017). Furthermore, renewable fuel biogas can be further transformed into green electricity, heat or vehicle fuel, chemicals, and proteins, and digestate used as fertilisers or recycled into other products such as fibres, clean water, and concentrated fertilisers (Holm-Nielsen et al. 2009).

## 2.3 Anaerobic digestion process chain

It consists of three main phases: the substrate chain (waste generation, collection, transport, supply to digester and pretreatment); the transformation processes (chemical and biological conversions of biowaste into the desired product); and the production chain involving the posttreatment of the digester outputs, their refinement into more valuable products), and the distribution and utilisation phase (Vögeli et al. 2014).

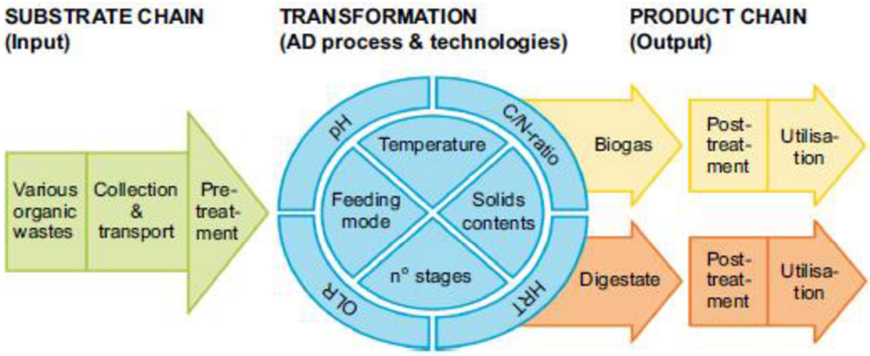


**Figure 1**: Summary of the anaerobic digestion (AD) process chain. Source: (Muh et al. 2018b).

## 2.4 Factors affecting biogas production

To obtain optimum biogas yields, several factors such as temperature, pH, C:N ratio, the organic loading rate, the mixing of the hydraulic retention rate (HRT), and the start-up and inoculation must be adequate and controlled.

### 2.4.1 Temperature

Temperature is vital in the AD process as it influences not only the activity of enzymes but also the yield of $CH_4$ and the quality of digestate quality. Anaerobic bacteria grow in different temperatures: psychrophilic at 10 - 30ºC, mesophilic at 30 - 40ºC; thermophilic at 50 - 60ºC (Zhang et al. 2014). AD occurs in all climates, but it is affected by temperature variations. The process is very slow in cold climates and on the other hand, extremely high temperatures can denature the microorganisms (Muh et al. 2018b). The digester could be buried under the ground while considering other parameters to overcome this. The ideal temperatures for AD are mesophilic with optimal activity at 37ºC and thermophilic temperatures with optimal activity at 55ºC (Vögeli et al. 2014).

### 2.4.2 Potential of hydrogen (pH)

The suitable pH range for optimal anaerobic digestion (AD) is a neutral range of 6.5 - 7.5 even though hydrolysis and acidogenesis occur under an acidic pH of 5.5 - 6.5 compared to methanogenesis that occurs between a pH of 6.5 and 8.2 (Vögeli et al. 2014). In situations of high acidity, a hydroxide or sodium bicarbonate is added to neutralise the pH of digesters (Vögeli et al. 2014).

### 2.4.3 Carbon to nitrogen (C:N) ratio

The C: N ratio is very important, and care must be taken when combining substrates to achieve a balanced ratio. It gives information on ammonia inhibition and nutrient deficiency with an optimal range between 16 and 25. High C:N yields result in rapid consumption of $N_2$ by methanogenesis and result in lower gas yield, while ammonia accumulates with the high pH, which is toxic to methanogenesis (Muh et al. 2018b). To solve this problem, substrates with high and low C:N ratios must be combined (Vögeli et al. 2014).

Muh et al. (2018b) explain organic loading rate as the measure of the amount of substrate fed into the digester at a given time is of utmost importance. This is particularly important in continuous reactor systems because overloading will cause an increase in volatile fatty acid content which will lead to acidification and failure of the system. The loading rates of the reactor 4 - 8kg VS/m3 reactor per day and the removal of 50 - 70% volatile solids are suitable for continuously stirred reactors and 2 kg VS/m3 for non-stirred reactors in developing countries according to studies (Vögeli et al. 2014).

### 2.4.5 Hydraulic retention time (HRT)

Muh et al. (2018b) define HRT as the time the liquid fraction remains in the digester. It is defined by the ratio of the digester volume to the input flow rate of the substrate. Mesophilic HRT ranges from 10 to 40 days, while thermophilic digestion is 5 days (Vögeli et al. 2014).

### 2.4.6 Mixing

Mixing is another important parameter to consider when managing biogas plants. According to Muh et al. (2018b), mixing and stirring the digester increases the bioavailability of substrates by mixing fresh materials and digestate which inoculates the fresh material with the microbes. This prevents the formation of scum which can clog the gas pipe or cause foaming over the digester which will hinder the temperature gradient within the digester. Too much foam will inhibit enzyme activity and prevent gas release from the slurry which can cause total system failure.

### 2.4.7 Start-up and inoculation

According to Muh et al. (2018b), newly built digesters are first inoculated with microbes before the AD process sets in. This is done using a 1:1 dilute mixture of cow dung and the cow dung should occupy 10% of the digester volume for a good inoculation. This is done because the microbe population must grow gradually before it becomes used to the substrate. After this is done, gradual feeding of the digester is maintained until a balanced microbial population is achieved. Initial overfeeding will lead to acidogenesis, which will affect methanogenesis, and a subsequent failure of the system may occur. $CO_2$ is the first gas to be produced followed by $CH_4$ of approximately 45% afterwards (Vögeli et al. 2014).

## 2.5 The history and evolution of biogas technology

Biogas is assumed to have been used to heat bath water in Assyria around 10 B.C. and it is alleged that anaerobic digestion of solid waste might have been well applied in ancient China (He 2010). Still, according to (He, 2010), the mid-19$^{th}$ century is the year in which there were documented facts about the anaerobic digestion of biomass by humans with digesters constructions in New Zealand and India, and it is around the 1980s that a sewage sludge digester was built in Exeter UK to power street lamps. In 1921, biogas was commercialised by Guorui Luo in China. In Germany, the first sewage plant to supply biogas to the public was constructed in 1920, and in 1950 it had the first large agricultural plant working in the same century around the 1970s, and the technology attracted much attention because of the surge in fuel prices which pushed people to search for alternate energy sources with Asia, North America leading the technology and Africa. In the 80s that is till around 1988, there were about 4.7 to 7 million biogas digesters in China. In 1999, India represented 3 million small-scale biogas plants. Of the recent, in 2007, China represented 26.5 million biogas plants for which household plants were dominated by digester volumes of 6 -10 $m^3$ (Chen et al. 2010).

## 2.6 Status of energy in Cameroon

Cameroon is still one of the countries in Sub-Sahara Africa (SSA) where energy production and use remain unsustainable. As a result, a larger part of the population depends on fuelwood commonly called firewood for cooking, lighting, and heating, especially in rural areas and in urban settings (Muh et al. 2018b). This is happening despite the richness of the country's soil and subsoil in natural resources.

The main sources of energy in Cameroon are hydropower, petroleum, coal, biofuels, and waste. The main energy source of the country is biofuels and waste, which account for 64.55% of its primary energy supply, followed by oil, which accounts for 22.5% of the primary energy source.

In terms of energy consumption, biofuels constitute up to 64.1% of the primary energy consumption of Cameroon, 27.2% for oil, 5% for hydro and 3.7% for natural gas. Electricity generation is dominated by hydropower (73.2%), oil 12.8%, natural gas 12.9% and biofuels 1% (REN21 2016). Small efforts have been made to harness other forms of renewable solar, wind and biogas energy.

According to Muh et al. (2019), Cameroon has an installed energy capacity of 1475 megawatts (MW) from hydro and thermal plants. The access to energy in the country is moderate because, in 2013, the electrification rate was 55%, with 10 million people without access to electricity. It had 88% urban and 17% rural electrification rates in 2016 (Muh & Tabet 2019). 46.6% of the country lives in rural areas while 54.4%lives in urban centres resulting in rural low energy access of 17% (REN21 2016).

Furthermore, Muh & Tabet (2019) attest to the fact that the country is endowed with colossal potential for renewable energy resources but the current level of utilization of these resources is low leaving the population with the only option of using solid biomass fuels for basic energy needs. Despite these enormous energy potentials, all resources are channelled into the development of the hydroelectric infrastructure. This has resulted in energy insecurity in the country, particularly in rural areas. Small-scale biogas and household biogas plants have proven to be able to solve these energy issues, and others such as China and India will be a good tool to use in Cameroon.

## 2.7 Merits and demerits of biogas technology

The benefits of biogas technology are overwhelming because it contributes to the management of organic waste which is intended to give rise to valuable products. However, there exist some disadvantages.

### 2.7.1 Merits of biogas technology

#### 2.7.1.1 Health

Subjecting human and animal waste reduces its pathogen content, which reduces the effect of pathogen development, contamination, and spread, making the health of users safer (He 2010). This is applicable in the case where biogas plants are connected to public toilets or in situations where waste is not dumped openly. China is a known example where there was a 90 - 99% reduction in schistosomiasis and a 13% tapeworm reduction (Remais et al. 2009) The bacteria are killed because retention times of 3 weeks at mesophilic temperatures are sufficient to kill pathogens that cause typhoid, cholera, dysentery, schistosomiasis, and hookworm (Itodo et al. 2021).

The health benefit resulting from the use of biogas is also that of biogas being a clean source of energy. Using traditional energy sources such as fuelwood for cooking and traditional lamps that use kerosene are detrimental to the short and long-term health of users and could lead to eye vision problems, lung problems, and cancers. For example, in Guatemala, a study between fuelwood use and reduced birth weight was documented, independent of key maternal, social, and economic factors, and found in more than 1700 women and newborn children, the percentage of low birth weight was 19.9% for open fire users compared to 16% for those using electricity gas (Boy et al. 2002).

#### 2.7.1.2 Economic impact

The positive economic impact resulting from the long-term use of biogas is due to the fact that energy-poor households result in poor households. This is called the energy burden, which is high in poor households because they turn to using a greater portion of their income in energy. A study carried out in China to see the effect of a decrease in the use of coal and wood and the increase in the use of biogas showed that the adopters were able to regain the construction cost in a period of 2 to 3 years (He 2010). The use of coal and wood was reduced by 68% and 74% respectively (Remais et al. 2009). Additionally, there was an estimated 20% increase in agricultural production resulting from the use of biogas slurry as slurry (GTZ 1999).

#### 2.7.1.3 Environmental impact

Our environment is one of the important spheres of intervention today. Its unconducive aspect affects everyone, especially the poorer people. Environmental problems have been on the rise since the last century, notably global warming resulting in climate change. Biogas technology has the potential to contribute to solving this environmental problem.

Global warming (GW) is the consistent global increase in the temperature of the Earth due to increased greenhouse emissions resulting from human activities which has resulted in climate change. Methane ($CH_4$) is the second most important greenhouse gas after carbon dioxide ($CO_2$) (McCarthy 2010). It has a global warming potential (GWP) of more than 20 times that of $CO_2$ over 100 years. Chen et al (2010) affirm that 33% of total anthropogenic $CH_4$ emissions come from the agricultural sector, particularly from ruminant animals in livestock and rice production. Estimates show that biogas production technology (BGT) could potentially reduce anthropogenic $CH_4$ by about 4%. On the other hand, nitrous oxide ($N_2O$), considered the highest human-induced threat to the ozone layer, has a GWP of 300 times greater than $CO_2$ (Ravishankara et al. 2009). BGT has the potential to curtail these emissions, which can only be achieved through increased use of the technology. Again, digestate a biogas slurry could reduce the overdependence on synthetic fertilisers reducing GHG emissions.

### 2.7.2 Demerits of biogas technology

#### 2.7.2.1 High cost

The high cost or the high initial cost of constructing a biogas plant is one of the significant reasons for not being able to adopt biogas, as observed when reviewing the literature. Although the cost of construction differs from country to country, it has been observed to be relatively higher than the income of farmers and other potential users (He 2010). In studies conducted in Thailand by Limmeechokchai & Chawana (2007) and in Kenya by Mwirigi et al. (2009), high costs were identified as a measure barrier to the adoption of the technology. In another study from a pool of seven Asian and African countries, farmers that were grouped as medium or high income were to be about 95% of those implementing the technology (Ni & Nyns 1996). In Kenya, 46 to 57% of the owners of fixed-dome and flexible bag plants received 25% subsidies to help them with the construction cost (Mwirigi et al. 2009).

## 2.8 Influencing factors for household decisions on the use and adoption of biogas technology

Influencing factors for household decisions on the use and adoption of biogas technology are factors that affect the adoption and use of biogas technology. Many studies have been carried out on factors that affect the adoption and use of biogas technology at the home level in different sites across the world. An overview of these works shows that the influencing factors are mostly sociodemographic with socioeconomic characteristics being the most important. This review of the literature defines these factors, recapitulates, and compares the results of different studies.

### 2.8.1 Demographic and socioeconomic factor Influencing household decisions on use and adoption of biogas technology

#### 2.8.1.1 Age

According to the Meriam Webster's dictionary, age is the length of an existence extending from the beginning to any given time.

As reported by Kelebe et al. (2017), Karakara & Dasmani (2019), age was found to be significant and positively related to the adoption of biogas technology in which older household heads had a higher likelihood of adopting the technology than younger ones. This was attributed to the fact that it is more likely that older people have capital and, therefore, can afford the cost of constructing and installing biogas plants. For example, in the case of cattle holding, there was a significant relationship between the elderly and the young in the number of cattle owned in which elderly people with an average age greater than 45.5 years owned 5 cattle, while young people of fewer than 45.5 years owned less than 3 cattle. Therefore, the possession of wealth expressed through a high number of livestock, high economic status, better experience, and greater affordability of biogas technology is greatly enhanced by age (Kelebe et al. 2017a). This is supported by Uhunamure et al. (2019), who said that the adoption of biogas technology is carried out mainly by the average to the high-income group due to the high investment cost. This result is like that of (Bekele et al. 2003; Kabir et al. 2013a).

On the other hand, Walekhwa et al. (2009a), and Amir et al. (2020) said that the probability of adopting biogas technology about the age of the household head was found to be negative, which is not significant indicating that younger household heads had a higher probability of adopting than older household heads. This showed that older people took less risk in the adoption of new technologies and as such were reluctant to make such decisions. This is in tandem with the results of (Geddafa et al. 2021). Amir et al. (2020a) also said that age is an important factor in innovations, and in their studies, the average age was 49.6 years because it involved household heads which revealed a possible labour source for biogas-related activities. Furthermore, age was also a drawback in the adoption by young people because they considered the work dirty as a result of the mixing of dung and also time-consuming Momanyi et al. (2016), which is similar to those of Wawa & Mwakalila (2021) who found out that young people do not like holding cow dung because they feel uncomfortable and fear infection by skin disease.

#### 2.8.1.2 Gender

Gender can affect the adoption of biogas technology either positively or negatively. Since rural energy consumption is dominated by women, houses whose heads of household are women are more likely to adopt biogas than their male counterparts (Amigun et al. 2008a).

In studies correlating the factors that influence household decisions on the adoption and use of biogas technology in South Africa, gender, whether male or female, is found to be significantly positive in influencing the adoption of biogas technology. Even though women are more involved in house chores, such as cooking, preparing firewood, and managing waste, it did not discourage men from embracing biogas adoption (Uhunamure et al. 2019a). Female dominance in house chores will differ according to settings, as most women will take on the catering needs such as preparing meals, while men will have more technical needs such as energy needs. This result is different from that of (Amigun et al.

2008b; Kabir et al. 2013b)who found that households dominated or headed by women in house chores were more likely to adopt technology than men.

### 2.8.1.3 Level of education

The literature on a multitude of social and field research has found that education is an important factor in influencing people's choices. Its importance can also be seen in the UN SDG 4, in which its target by 2030 is to achieve universal primary education. This is because education empowers people, and a certain level of education will lead people to make informed decisions.

In the article 'Determinants of Biogas Technology Adoption in Southern Ethiopia' by Shallo et al. (2020), it was found that households with a higher level of education were more likely to adopt the art than those with lower levels. The relationship between the adoption of biogas and the level of education was positive and significant. Likewise, the significant mean difference in the level of education between adopters and non-adopters was also significant. This is supported by (Mwirigi et al. 2009; Kabir et al. 2013a; Kelebe et al. 2017a; Uhunamure et al. 2019a).

In another study by Geddafa et al. (2021a) in north-western Ethiopia, it was found that schooling or literacy had a favourable and important factor correlated with the acceptance of the effect of biogas on biogas adoption, implying that illiterate households will be more reluctant to accept it. The possible justification was that educated households are more likely to embrace new technologies, while a low level of education hinders the productive flow of knowledge about new technologies for decision making. These results were consistent with those of Geddafa et al. (2021a) and Abbas et al. (2017a), who found a positive correlation between the level of education and the application of biogas technology in Ethiopia.

### 2.8.1.4 Household size or family size

According to the United Nations (2017), a household is a group of individuals who share basic needs such as food, shelter, and other necessities for survival. In human society, it is the major socioeconomic unit.

Household size plays a dual role in the adoption and use of biogas which could be positive or negative. Positively, larger households will likely adopt and use biogas technology because they can provide the labour needed to sustain the plant. The larger household could also negatively influence the art since it can be a burden to the finances of the family (Amir et al. 2020a). This implies that in some situations, smaller to average households could likely adopt the art than large households. The results of Amir et al. (2020a), which is in line with those of Momanyi et al. (2016); Kelebe et al. (2017); and contrary to those of Abbas et al. (2017); Geddafa et al. (2021) showed that family size is positive and significant in biogas adoption.

#### 2.8.1.5 Income

Income is an important variable to measure when considering the purchasing power parity of individuals. At the household level, it becomes more challenging as household members turn to rely on the father, mother, on others that is the one has more resources control in the home. The financial strength of the household will depend on how much income they have which could be measured daily, monthly, in semesters and annually which determines their decision in engaging into activities that need reasonable income at the start.

When conducting studies on the factors that influence biogas technology adoption in a region in Pakistan, households were grouped into two: those with low income and those with higher income. It was found that households with higher incomes were more likely to adopt biogas than those with lower incomes. The result is correlated with that of Abbas (2017a), who found a positive link between income and the probability of adopting biogas.

#### 2.8.1.6 Number of cattle or livestock owned

The number of cattle or livestock owned in many biogas studies has advocated the number of cattle or livestock as a significant factor positively correlated with the adoption and use of biogas technology. It could be a result of its availability, high biogas content, and waste management purposes. Therefore, ownership of livestock by households, whether cattle, poultry, pigs, sheep, or goats, will have a positive influence on the adoption of biogas.

In a study carried out in Ethiopia, the increase in the number of cows possessed by a household unit by one head of cow increases the likelihood of obtaining biogas, as cow dung is the main substrate for biogas production in Ethiopia. Therefore, larger amounts of cattle are more likely to be attributed to the implementation of biogas technology in households than small amounts. This observation is consistent with that of Mengistu (2016) and Kelebe et al. (2017), who found a good connection between the number of cattle and the adoption of technology.

In another study done in the Northwest of Cameroon by Kimengsi (2015), the lack of enough domestic animals to produce waste for biodigesters to produce enough gas for lighting due to small-scale farming systems was a technical challenge in adopting biogas technology. This deficit could also be attributed to people, who turn to rely solely on animal waste for biogas production, neglecting other organic sources of waste. Furthermore, the area, although it was a cattle ranching hub, did not favour the adoption of biogas because of the system of cattle ranching, a free-range grazing system that makes it difficult to collect the dung to be used in the digester.

Therefore, the ownership of cattle or livestock is not enough to determine the possible adoption and use of biogas by households but also the method of animal rearing is important.

## 2.9 Analytical framework

The analytical framework provides a visual illustration of the study's variables. In this research, the dependent variable is the adoption and use of biogas technology. The adoption and use of biogas are influenced by several independent interconnected variables.

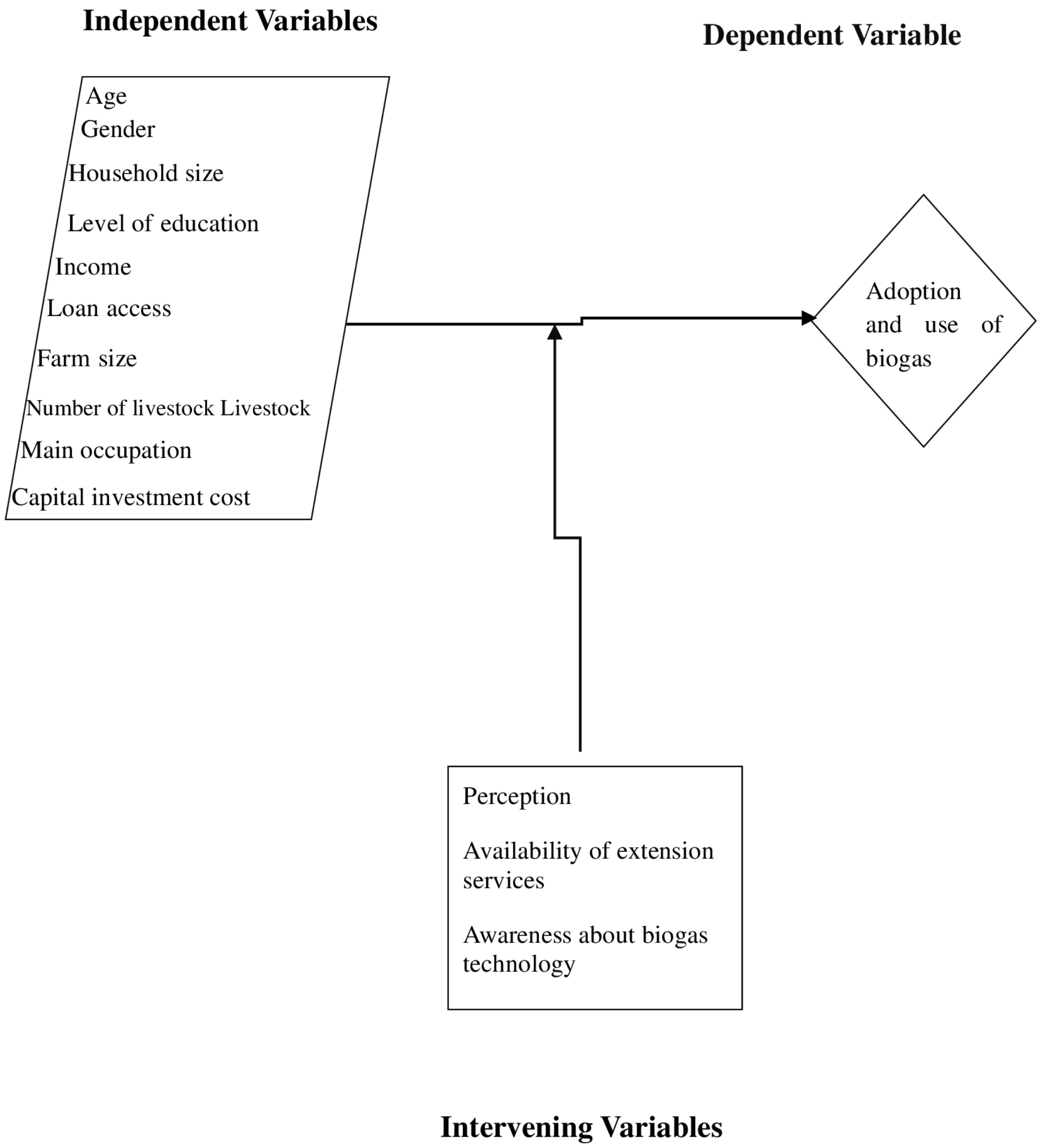


**Figure 2**: Schematic representation of analytical framework showing the relationship between independent variables, dependable variable, and the intervening factors

# 3 Aim of the thesis

This piece of work, titled Influencing Factors for Household Decisions on Adoption and Use of Biogas Technology: The Case of Bamenda, Northwest Region of Cameroon,' has as its aim revealing the factors underlying the adoption and use of biogas technology at the household level, showing the key variables that influence the adoption and use of biogas technology. In other words, it will contribute to revealing the current state, bottlenecks, and perspectives of biogas plants in the area and country at large.

## 3.1 Research questions

- What demographic and socioeconomic characteristics do household heads possess?
- What is the state of art of biogas technology in the study area?
- What factors influence household decisions on the use and adoption of biogas technology?

## 3.2 Objective

The main object of this study is to identify the factors influencing household decisions to adopt and use biogas technology.

### 3.2.1 Specific objectives

- To describe the demographic and socioeconomic characteristics of biogas users and non-biogas users.
- To investigate factors influencing household decisions on the use and adoption of biogas technology.
- To describe biogas technology in study sites.

# 4 Methods

## 4.1 Description of study area

The study area Bamenda is in Mezam Division, Northwest Region of Cameroon. It is divided into seven villages namely Bamendakwe, Mankon, Nkwen, Ndzah, Chomba, Nsongwa, and Mbatu under Bamenda I, Bamenda II, and Bamenda III municipalities. With an altitude of 1258 meters above sea level, it lies between latitude 5˚55'0"N and 6˚0'0'N Equator and longitude 10˚7'30"E and 10˚10'0'E of the Greenwich Meridian (Fombe & Acha 2020). The study was carried out in Bamenda III (Nkwen), comprising the neighbourhoods of mile 3 Nkwen, mile 4 Nkwen, mile 6 Nkwen, and in Bamenda I (Bamendakwe) precisely in the Bangshei neighbourhood. As shown in Figure 1, the town is bordered to the west by the Bali sub-division, to the north, by the Bafut sub-division, to the northeast, by the Tubah sub-division, and to the south by the Santa sub-division.

According to the last population census in 2005, the area had 1,728,953 inhabitants with a density of 100/km$^2$ (Innocent et al. 2016). Today, the population is approximated to be around 2 million people. It has two main seasons, the rainy season, which starts on 15 March and ends on 15 November, and the dry season from 15 November to 15 March, although faced with recent seasonal fluctuations. The average annual rainfall is approximately 2400 mm, with an average temperature of 23°C (Esculenta & Wjert 2017). According to Ojong (2011), the economy is made up of heterogeneous economic activities such as farming, food vendors, carpenters, motto taxi riders, and tailors among others. Farming activities are carried out in the peripheries of the city.

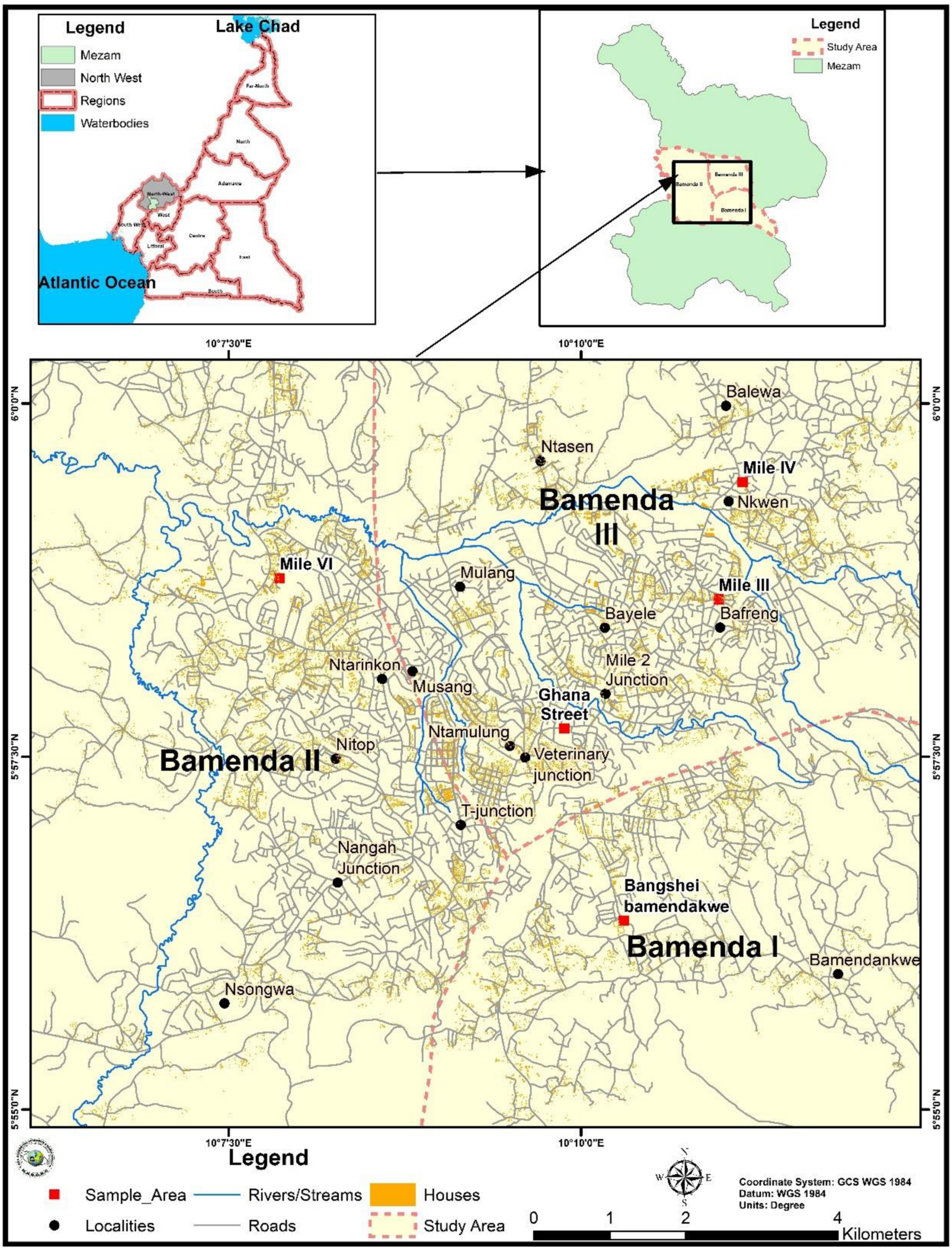


**Figure 3**: Geographic and administrative map of the study area

The hydroelectric energy situation in Bamenda is critical, characterised by irregular supply. Hydroelectricity, the main source of energy used in lighting, is not effectively managed and has led people to look for other alternatives such as solar energy to fill this gap. For cooking, firewood is used while liquefied petroleum gas (LPG), kerosene, charcoal, and sawdust are also used to meet the need. As a result of the high cost of these fuels, people are looking for better energy sources. Biogas used in some households in Bamenda was established by extension officers from the SHUMAS biogas training centre, the Heifer organisation, and other resourceful individuals.

### 4.2 Data collection and sampling method

Data collection was carried out at the household level with the household being the main target. It was carried out mainly in the four localities (mile 3, mile 4, mile 6, in Nkewn, and Bangshei in Bamendakwe) between 20 September 2023 and 13 October 2023. The areas in the periphery of the city were chosen specifically due to the availability of farmers, energy shortages, and the presence of biogas plants.

Semi-structured self-administered questionnaires and interviews were used to extract primary data from respondents in the households (see Appendix 1). The data collected included demographic information, socio-economic, awareness and perception, and experience in biogas technology. These questions were developed based on the research objective from the literature review of works related to the adoption and use of technology with the help of members of the biogas research team and curated by the supervisor. The English language was the primary language of interviews, making use of French and pidgin appropriate to ease communication. The target population was users and non-users of biogas households and a total of 129 households were administered paper questionnaires out of which 112 were non-users and 17 were users (see Table 5). Quantitative and qualitative data was collected with the use of open and close-ended questions. This was done through a multistage sampling in which cluster and systematic sampling were used for biogas non-users and snowball sampling for biogas users.

**Table 1: Data collection localities**

| Municipality | Locality | HH-non biogas users | HH-biogas users |
|---|---|---|---|
| Bamenda I | Bangshei, Bamendakwe | 0 | 8 |
| Bamenda II | Ghana Street, Nkwen | 8 | 0 |
| Bamenda III | Mile 3 Nkwen | 69 | 3 |
| | Mile 4 Nkwen | 14 | 4 |
| | Mile 6 Nkwen | 21 | 2 |
| Total | | 112 | 17 |

## 4.3 Data analysis

Descriptive statistics and the logit regression model have been used to analyse the data. For descriptive statistics data was entered into Microsoft Excel spreadsheets, cleaned, coded, and thereafter transferred to the statistics and data (STATA) software to compute percentages and frequencies. To answer the research question: What factors determine household decisions on use and adoption of biogas in Bamenda, Northwest Region of Cameroon? The logit regression model was used. The logit regression model (multivariable or multiple logistic regression) used in these studies is represented as follows:

Multiple logit regression model.

$$\log = \left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = B_0 + B_1x_1 + B_2x_2 + B_3x_3 + B_4x_4 + B_5x_6 + B_6x_6 + B_7x_7 + B_8x_8 + B_9x_9 + B_{10}x_{10} + B_{11}x_{11} + B_{12}x_{12} + B_{13}x_{13} + B_{14}x_{14} + \alpha_i \quad \ldots\ldots\ldots\ldots(1)$$

Where j is the measure of multiple repeated observations in the area $i$.

$B_0$ is a constant,

$B_1$, $B_1$, … … ….. $B_{14}$, are the coefficients to be determined.

$x_1, x_2, \ldots \ldots \ldots . x_{14}$ are independent variables that influence household decisions on the use and adoption of biogas technology (predictors),

$\alpha_i \sim N(0, \sigma_\alpha^2)$ random effect is assumed to have a mean of zero and constant covariance in a normal distribution (Kalan et al. 2021).

And $\pi(x) = P\left(Y = \frac{1}{X} = x\right)$ is a dichotomous independent variable Y with two categories.

In adoption studies, the logit and probit models are frequently used, but the logit is preferable because it makes calculations easy (Amir et al. 2020b).

## 4.4 Variables used in the study

Most of the variables assumed to influence household decisions about the use and adoption of biogas technology in this study were chosen from the review of studies on the adoption of biogas and some based on field experience. The literature shows that various factors determine the use and adoption of biogas and differ by region**.** The independent variables are demographic (age, gender, household size, level of education, main occupation) and socioeconomic (number of livestock, income, farm size, loan access, capital investment cost, perception, availability of extension services, and awareness of biogas)**.** The variables are explained in the Table 2 below.

**Table 2: Description of variables for the use and adoption of biogas technology**

| Variable | Type | Description |
|---|---|---|
| Age | Continuous | Age of the head of household in years |
| Gender | Binary | Sex of the household head (0 = female, 1 = male) |
| Level of education | Categorical | Different categories or levels of education |
| Household size | Continuous | Number of persons in the household |
| Income | Categoric | Income of household head in FCFA with varying amounts |
| Loan access | Binary | Access to loan by household head (0 = no, 1 = yes) |
| Farm size | Continuous | Farm size in hectares at the household level |
| Number of livestock | Continuous | Number of livestock in the household |
| Main occupation | Binary | Main occupation of household head (0 = not farmer, 1 = farmer) |
| Capital investment cost | Binary | Capital investment cost considered by the household head (0 = low, 1 = high) |
| Perception | Categoric | Perception of benefits of biogas technology by the household head |
| Awareness about biogas technology | Binary | Awareness by household head (0 = no, 1 = yes) |
| Availability of extension services | Binary | Presence of extension services (0 = no, 1 yes) |

## 5 Results and discussion

### 5.1 Characteristics of households in the study area

Out of 129 respondents, 112 (86.8%) persons were non-biogas users while 17 (13.2%) were biogas users. The highest number of participants were between 28 - 37 (25.6%) years old followed by persons in the 18-27 years age group while individuals 58 years and above had the lowest percentage (5.4 %). The majority of respondents were females (51.2%). Regarding the size of the household, more than a quarter of the households had 6 members (28.7%). Most of the respondents were graduates (25.8%) while those without formal education were the lowest in percentage (6.2%). Regarding income, most of the respondents had a monthly income of less than 40,000 FCFA, while only 5 (3.9%) had a monthly income of 240,000 - 290,000 FCFA. Loan access was possible among 75 (58.1%) compared to 54 (41.9%) who did not have loan access. Majority of respondents 81 (62.8%) owned land. Most of the respondents 50 (38.8%) did not have hectares of land, while only 2 (1.6%) had 2 hectares of land. Only a few respondents owned livestock (at least 1 cow) 0.8% compared to the majority who did not own livestock 107 (82.9%). Out of 129 respondents, 100 (77.5%) were non-farmers, 113 (87.6%) had awareness of biogas, and 108 (83.7%) stated that high capital investment cost was a problem. Concerning perception, most respondents 87.6% (113) saw biogas usage as cost-beneficial (see Table 5).

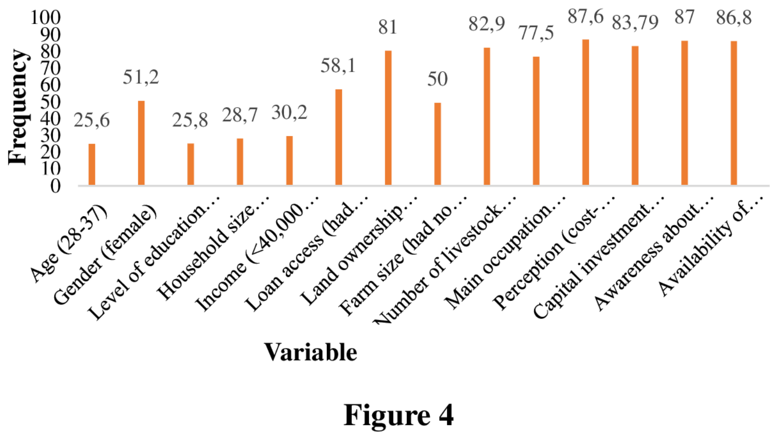


**Figure 4:** Bar chart showing variables and their frequencies

## 5.2 Description of biogas technology in study sites

### 5.2.1 State of the art

Biogas technology adoption and use in Bamenda Northwest region of Cameroon is still in its early stages. Field observations show that just a relatively small number of farmers and non-farmers have adopted and are using biogas technology. Household biogas plants range in size from 10 - 25 $m^3$ and are domed-shaped. Some biogas plants are connected directly from the latrine, where the substrate is human waste, whereas some use animal waste, household waste, and farm waste to feed the plant. The plants are buried in the ground, constructed with local materials such as earth or cement bricks, and cement mortar, and locally or exported materials such as iron rods and pipes are also used. The energy derived from these plants is used mainly for cooking and the bi-product digestate is used as organic fertilizers. They use modified cookers for the biogas (see Figures 6, 7, 8 and 9). On the other hand, large-scale biogas technology has been implemented in institutions such as hospitals and schools.

### 5.2.2 Energy use in Bamenda, Northwest Region of Cameroon

The main source of energy used in lighting in Bamenda is hydroelectricity. This is the same all over the national territory. Results in Bamenda show that all 129 households have hydroelectricity as the main energy at the household for lighting and powering appliances. For cooking, fuelwood is the main source of energy of which 112 households had it as their main energy for cooking coupled with charcoal, and kerosene in a few cases. Biogas plants are very few, particularly functional ones and very few people use them and combination with other sources. Solar energy generated from solar panels is used in lighting and powering of appliances.

**Table 3: Distribution of Energy Use**

| **Type of Energy** | **Electricity** | **Fuelwood** | **Biogas** | **LPG** | **Charcoal** | **Kerosene** | **Solar** |
|---|---|---|---|---|---|---|---|
| **No. of HH** | 129 | 112 | 17 | 27 | 3 | 2 | 6 |

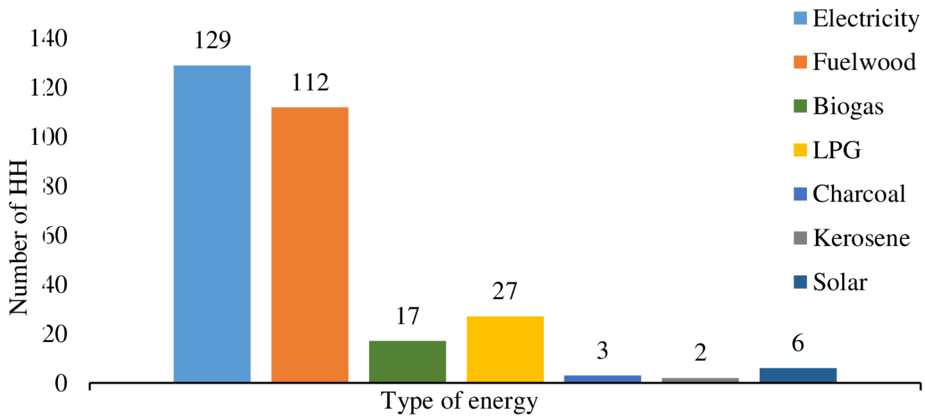


**Figure 5**: Graphical representation of energy type used.

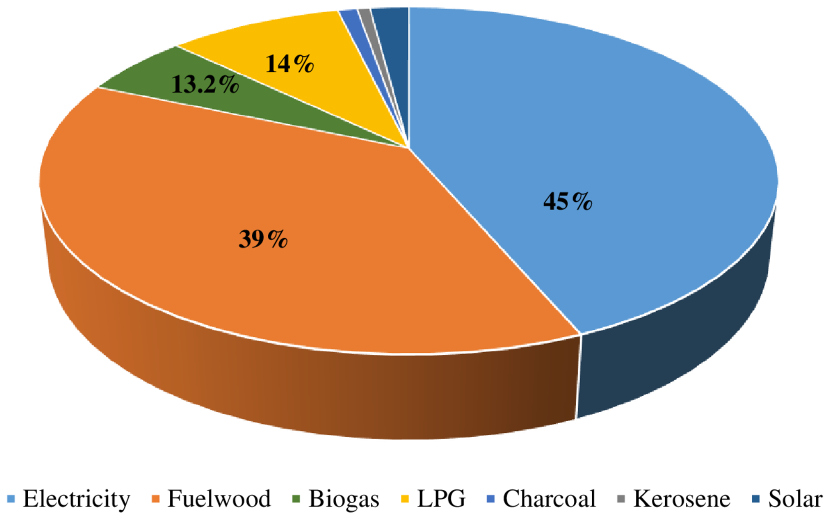


**Figure 6:** Pie chart showing the percentage use of energy types.

**Table 4: Logit regression results**

| Variable | Beta coefficient | Standard error | Significance | Odds ratio exp. of beta |
|---|---|---|---|---|
| Age of respondent | -0.003 | 0.221 | 0.30 | 0.929 |
| Gender | 0.052 | 1.298 | 0.81 | 1.799 |
| Household size | 0.0263 | 0.335 | 0 .51 | 1.427 |
| Level of education | 0.020 | 0.369 | 0.75 | 1.248 |
| Income | 0.006 | 0.244 | 0.42 | 1.097 |
| Loan access | -0.006** | 0.603 | 0.05 | 0.968 |
| Land ownership | -0.011** | 0.746 | 0.02 | 1.013 |
| Farm size | 0.118 | 2.387 | 0.90 | 2.544 |
| Number of livestock | 0.075*** | 0.746 | 0.34 | 1.765 |
| Main occupation | 0.044 | 1.494 | 0.69 | 1.786 |
| Awareness of biogas technology | -0.016 | 0.998 | 0.13 | 0.858 |
| Capital investment cost | 0.002 | 0.840 | 0.14 | 0.869 |
| Perception | -0.006 | 0.583 | 0.21 | 0.870 |
| Availability of extension service | 0.195*** | 3.178 | 0.10 | 4.46 |
| Constant | -0.140 | 0.100 | 0.63 | |

*, ** and *** Significant at 10%, 5% and 1% level; Log likelihood: -38.250; Pseudo $R^2$: 0.23; Chi-square: 24.06

## 5.3 Logistic regression results

### 5.3.1 Influencing factors for household decisions on adoption and use of biogas technology

The logit regression analysis is the most widely used analysis to determine factors that affect the use and adoption of biogas in developing countries. Demographic, socioeconomic, and other factors are significant and positively correlated in many studies with a few exceptions. In this study, the model is suitable because the probability associated with F-statistics (prob > F = 0.0035) is less than 0.05 meaning that some of the independent variables are significant and influence decisions on the use and adoption of biogas. Furthermore, the $R^2$ value of 0.2371 means that 23.71% of the variability in the dependent variable can be explained by the fitted model. The variance inflation factor (VIF) between the variables was between 1 and 2 showing that there was no strong multicollinearity among the variables that could distort the results. The model was tested in the 10%, 5%, and 1% confidence intervals, and the 5% confidence interval was adopted as the widely used. The analysis showed that out of the fourteen independent variables, only two variables, loan access and land ownership were statistically significant. This could be because the standard error of three independent variables was greater than 2, indicating a possible problem of values among the independent variables. Land ownership and loan access were significant, with a negative influence on the decision of the household for the use and adoption of biogas. The other factors: availability of extension service, farm size, gender, main occupation, number of livestock, household size, level of education, income, age of household, perception, capital investment cost, and awareness about biogas technology were statistically non-significant.

#### 5.3.1.1 Land ownership

Land ownership is often not considered in biogas technology studies. Rather, what is considered is the farm size or cultivated land. It is appropriate in this context because of the many non-biogas users and because the area is semi-urban. Respondents who did not own land admitted they could not consider the idea of constructing a biogas plant while those who owned land considered it as an option. Land ownership was significant (p = 0.02) with a negative correlation on biogas use and adoption. The odds ratio of 1.013 suggests that for a one-unit increase in land ownership, the odds of adopting biogas decrease by approximately (1.013). Nevertheless, these results are similar to that of (Kelebe et al. 2017b) who found that the suitability and size of plots for residences were statistically not significant in the adoption of biogas technology.

#### 5.3.1.2 Loan access

Financial need was a vital factor in which respondents said they would not be able to undertake a biogas project due to limited financial resources and therefore other alternatives were considered such as access to a loan. In Cameroon, loan access in conventional financial institutions like banks necessitates a stable source of income and proof of valuable assets when affiliated with these institutions, which comes with high interest rates. This is therefore a drawback to many who cannot meet the requirements and as a result, they will go for less demanding and cheaper loans in microfinance, “njangi” groups (community-based financial support systems), and friends, or stay away from loans at all. In the study area, people prefer small banks like microfinance and other informal institutions. These institutions do not grant specific loans for biogas projects, but the respondents acknowledged that knowing the benefits of owning a biogas plant and considering the need, they could take loans for biogas projects.

However, the results obtained showed that, although loan access was significant (p = 0.05), with a negative influence on household decisions regarding the use and adoption of biogas technology. The odds ratio of 0.968 implies that for a one-unit increase in loan access, the odds of adopting biogas decrease by approximately 0.968 times. In terms of significance, this result is similar to that of Amir et al. (2020b) whose result was significant at a 5% interval level with a p-value of 0.0375. It is also similar to that of Marie et al. (2021b) at the

5% interval level, who had a p-value of 0.058 in which there was no statistical significance between access to loans and credit. On the other hand, this result is contrary to that of Gwavuya et al. (2012); Mengistu et al. (2016b); Kelebe et al. (2017b); Uhunamure et al. (2019b); Amir et al. (2020b); and Shallo et al. (2020b) who found loan access/credit to have a positive influence on the adoption of biogas technology.

#### 5.3.1.3 Availability of extension services

Extension services such as training, installation and maintenance services are important in the adoption decisions of biogas at the level of the household (Katuwal 2022). Results showed that having access to extension services is not positively associated with the use and adoption of biogas technology. The coefficient is positive and statistically insignificant (p = 0.10). This is in line with the result of Katuwal (2022), who obtained a non-significant correlation of extension services in Nepal.

#### 5.3.1. Farm size

Farm size has been shown to influence the use and adoption decisions of biogas technology (Walekhwa et al. 2009b; Kabir et al. 2013b; Mengistu et al. 2016b). In this study, the size of the farm did not influence the decision of households about the use and adoption of biogas technology, which had a probability value (p = 0.90) and a positive coefficient. It is not statistically significant. This is consistent with that of Shallo et al. (2020b) and inconsistent with the findings of (Abbas et al. 2017b; Amir et al. 2020b).

#### 5.3.1.5 Gender

In Cameroon, household decisions are taken by the household head, which could be the man, woman, or both. In this study, 52.2% of the heads of household were women, contrary to expectations, which could be explained by the fact that the men had left the region due to insecurity and slow economic activities. At a 5% significant level, gender was positive and statistically nonsignificant (P = 0.81) meaning that it does not influence household decisions about the use and adoption of biogas technology. According to this study, women were more likely to adopt biogas than men. This result is consistent with that of Kabir et al. (2013b), in which households headed by women had a higher chance of adopting biogas technology than households headed by men and differing with that of Amir et al. (2020b), in which males had a higher probability of adopting the technology than females at the household level.

#### 5.3.1.6 Main occupation

In this study, the main occupation was considered only to be farming and other occupations classified under non-farming even had farming as a secondary occupation. Non-farmers were 75.5% of the total population indicating that they had a greater likelihood of adopting biogas technology than non-farmers. This revealed a non-significant association with the household's decision to adopt biogas technology with a positive coefficient and P-value of 0.69. This result is similar to that of (Luo et al. 2021) in which the occupation of the household had no significant association with the use and adoption decision of biogas.

#### 5.3.1.7 Number of livestock

The number of livestock or heads of cattle is an indispensable variable when it comes to adoption decisions study of biogas technology at the household level. Households had poultry, goats, pigs, and cows as livestock. To simplify calculations, we converted the number of livestock to cows using the following information. ‘Providing biogas to a household size of 5 to 7 members with a plant of 8 $m^3$ will require 60 to 80 kg of organic waste per day which will need approximately 5 mature cows or 50 pigs or 600 poultry birds and 60 to 80 litres of water’.

The analyses revealed that the number of livestock owned by the household was statistically insignificant meaning that it does not influence household decisions on the use and adoption of biogas technology with a positive beta coefficient and a probability of (P = 0.34). The findings are correlated with that of Luo et al. (2021) whose studies revealed a non-significant relationship between the number of livestock with a household decision to adopt biogas. However, it is different from that of Mengistu et al. (2016b); Uhunamure et al. (2019b); Amir et al. (2020b) and Meidiana et al. (2020) who found the number of livestock to be significantly positively correlated with household adoption decisions of biogas technology.

#### 5.3.1.8 Household size

The size of the household is a cardinal factor in biogas adoption studies due to the labour needed. The size of the household was not statistically significant, which means that it does not influence the household's decisions about the use and adoption of biogas technology with a negative beta coefficient and a probability of (P = 0.51). The finding is synonymous with that of Mengistu et al. (2016b) who found the household size to be non-significant and different from those of (Walekhwa et al. (2009b); Uhunamure et al. (2019b); Amir et al. (2020b)), who found the household size to be significant and positively correlated.

#### 5.3.1.9 Level of education

The level of education of the head of education was found to not be statistically nonsignificant (P = 0.75) in the decisions of the household about the use and adoption of biogas technology, which implies that it had no impact on the dependable variable. However, the positive beta demonstrated that most of the educated respondents are more likely to adopt biogas technology because 25.8% were graduates and only 6.2% had no formal education. The findings do not agree with those of (Walekhwa et al. (2009b); Mengistu et al. (2016b); Uhunamure et al. (2019b), who found the level of education to be relevant and positively correlated with biogas technology adoption decisions.

#### 5.3.1.10 Income

Income was statistically insignificant meaning that it does not influence household decisions on the use and adoption of biogas technology. It had a positive beta coefficient and a probability of (P = 0.42). This aligns with the results of Luo et al. (2021), who found that income does not have an impact on household decisions to adopt biogas technology. Contrary to this, the works of Uhunamure et al. (2019b), Amir et al. (2020b), and Ngala et al. (2020), prove that household income is a significant and positive independent variable in biogas adoption.

#### 5.3.1.11 Age of Household Head

The statistical analysis revealed that the age of the person who leads the household does not have a significant impact on the decisions related to the utilisation and adoption of biogas technology. This is indicated by its statistically insignificant status, as evidenced by a negative beta coefficient and a probability value of (P = 0.21). This is similar to the results of (Mengistu et al. (2016b); and Luo et al. (2021), which differ from those of (Uhunamure et al. 2019b).

#### 5.3.1.12 Perception

The perception in this study was classified in terms of benefits and 87.6% saw the use of biogas as cost-beneficial. However, the perception was statistically insignificant, which implies that household decisions about the use and adoption of biogas technology are not affected by it. It had a probability of (P = 0.30) and a negative beta coefficient of -0.006 implying that an increase in perception had a greater chance of reducing the adoption of biogas technology.

#### 5.3.1.13 Capital investment cost

Capital investment cost was in terms of initial investment and long-term investment. 83.7% of respondents said that the initial investment cost was low. The statistical non-significance of capital investment cost implies that it does not play a significant role in shaping household decisions regarding the use and adoption of biogas technology. This conclusion is supported by a positive beta coefficient and a probability value of (P = 0.14) implying that most of the respondents have a higher probability of adopting the technology.

#### 5.3.1.14 Awareness of biogas technology

The lack of statistical significance in awareness of biogas technology suggests that household decisions regarding its use and adoption remain unaffected by such awareness. This is indicated by a probability of (P = 0.13) and a negative beta coefficient. This is different from the results reported by Geddafa et al. (2021b); and Amir et al. (2020b), who found that awareness of biogas technology is significant and positively correlated with the adoption of biogas technology at the household level.

## 6 Conclusion

The main objective of the study was to find out what factors influence household decisions on the adoption and use of biogas technology. Descriptive statistics were used to establish the frequencies of the respondents and multiple logit regression to find the factors that influence the adoption and use of biogas technology. First, the results showed that land ownership was significant with the use and adoption of biogas technology. This means that the increase in land ownership led to a decrease in the adoption rate. Secondly, loan access had a significant impact and negative relationship to the adoption of biogas technology, demonstrating that the more people had access to loans, the greater the likelihood of not adopting biogas. Third, variables such as age, gender, household size, level of education, income, farm size, capital investment cost, main occupation, perception, availability of extension services, and awareness of biogas technology were not significant in the adoption decisions of biogas technology.

There were limitations in finances and time to cover a large sample size. Therefore, it is recommended that future work in this area cover large sample sizes, particularly farmers and biogas users while looking at different perspectives. More studies are needed considering factors such as politics, culture, and technology, using other appropriate methodologies Another limitation might stem from the fear of the unknown among respondents, potentially leading to compromised data quality. This could be attributed to an ongoing conflict in the region, such as the armed conflict that has persisted since 2017. The rate of adoption of biogas technology is low in Cameroon's households and very low in Bamenda despite available resources as shown by the findings. On the other hand, large-scale biogas technology has been implemented in institutions such as hospitals and schools. The government and other stakeholders must implement strategies that will lead to the widespread adoption and use of biogas technology by its household population. This could be through policies, educational programs, and the provision of subsidies.

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