PERCEPTIONS AND WILLINGNESS TO PAY FOR DOMESTIC BIOGAS SYSTEMS IN GULU AND KITGUM DISTRICTS, NORTHERN UGANDA

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DECLARATION

I, **Natandula Sylivia,** declare that the work presented in this dissertation is my original work, and has never been published, submitted, or presented for any academic award in Gulu University or any other institution of higher learning.

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To my beloved mother, Agnes Auma, I hope I have made you proud!

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LIST OF ABBREVIATIONS AND ACRONYMS

CV	Contingent valuation
CVM	Contingent valuation Method
GHG	Greenhouse Gas
GUREC	Gulu University Research Ethics Committee
Mt	Metric tons
NDPIII	Third National Development Plan of Uganda
NGOs	Non-Governmental Organizations
RET	Renewable Energy Technologies
SAS	Senior Assistant Secretary
SDG	Sustainable Development Goal
SNV	Netherland Development Association
TLU	Tropical Livestock Unit
UBOS	Uganda Bureau of Statistics
UN	United Nation
VIF	Variance Inflation Factor
WTP	Willingness-to-pay

ABSTRACT

Domestic biogas is a more sustainable and effective greener fuel with the ability to substitute fossil fuels as the main source of energy for domestic chores like cooking and lighting. Despite the promotion of biogas by different agencies, only few domestic gas systems have been established in Uganda. The study therefore was on perception and WTP for domestic biogas systems in Gulu and Kitgum districts, northern Uganda. Specifically, the study characterized cattle producing households by their socio-economic status, determined the factors influencing households' perception of domestic biogas systems and ascertained the determinants of households' WTP for the systems. Using a cross sectional approach, data was collected using the 5-point Likert scale and Contingent Valuation Method (CVM) from 250 sampled households. Analysis was done using descriptive statistics, binary logit and the double hurdle model. The binary logit model results revealed that perception of domestic biogas systems was influenced by gender, household location, marital status, household income, livestock management system, access to adequate animal waste, and access to biogas technicians. The Double hurdle model indicated that WTP for domestic biogas systems was influenced by perception score, distance to firewood source, Tropical Livestock Unit (TLU), water availability, access to technicians, location and gender. Payment levels for domestic biogas systems were influenced by gender, paraffin use, tropical livestock unit, and participation in biogas project. The study recommended enhancing household's access to biogas technical services by NGOs, Government and private sector; and incentivizing households to participate in biogas project activities like trainings and demonstrations such that they can acquire adequate knowledge on the technology.

K**eywords:** *domestic biogas, perception, willingness to pay, contingent valuation, double hurdle*

CHAPTER ONE: INTRODUCTION

1.1 Background

Energy is paramount for most daily activities and operations across the globe (Rao *et al*., 2012). It is very essential for economic growth as well as a driver of livelihoods and wellbeing (Mengistu *et al*., 2015). In terms of poverty alleviation, no nation has increased per capita income and substantially reduced poverty levels without significantly ensuring energy security (Day *et al*, 2016; Rao *et al*., 2012; Oyeleke & Akinlo, 2020; Ikram *et al*., 2020) thus a positive relationship between the consumption of energy and a country's economic development (Obaideen et al., 2022).

According to Kaygusuz (2012) around 772 million people worldwide do not have electricity . Singh *et al*. (2019), asserts that the world-wide energy demand is growing at a rate of 1.5% annually, and it is expected to climb up by up to 27% by 2030 (Gielen *et al*., 2021) owed to the rising global population, economic and industrial expansion. However, the supply of energy is not increasing proportionately. Because of global energy poverty, most people rely on traditional low-quality energy sources. For instance, 80% of the global energy is generated from fossil fuels like oil, natural gas and coal that are not renewable and rapidly diminishing (Singh *et al*., 2019), and their combustion adds significantly to carbon dioxide emission - a greenhouse gas linked to climate change (Uhunamure, 2019). If global consumption of non-renewable energy continues at the current rate, they will get depleted very soon (Shafie *et al*., 2011).

While renewable energy sources such as hydro, solar, and wind are helping to fulfill growing global energy demand, their contribution remains relatively low (Lim & Biswas, 2019). As a

result, if no measures are taken to assure continual gains in energy efficiency, the world would require twice as much energy as it now generates by 2030 (Blondeel *et al*., 2021). Several collaborative attempts to enhance access to sustainable energy have been made (Solaun & Cerdá, 2019; Baena-Moreno *et al*., 2019). Never the less, there is still a strong reliance on nonrenewable energy supplies globally (Florio *et al*., 2019; Nosratabadi *et al.,* 2019).

Africa has a diverse range of energy resources, including wind, solar, hydro, and biomass (Nyiwul, 2017). The region contains around 12% of the global hydropower potential. Sub-Saharan Africa (SSA) in particular possesses renewable energy potential that can meet its demand. Yet, the region still suffers the most from limited access to energy (Nathaniel *et al*., 2020). According to Ebhota (2019), about 70% of the global population without electricity reside in Sub Saharan Africa, and electricity reaches only about a half of its population. About 890 million people in this region still look up to traditional low-grade biomass for cooking, with only one third enjoying clean cooking. More so, up to 80% of the total energy needs in the region are met using traditional biomass, higher than the 30% average in most of Africa (Kebede *et al*., 2010). This lack of energy access is a bottleneck to economic growth and sustainable development in the SSA region (Luo & Xu, 2018). For instance, The International Monetary Fund (IMF) in 2018 estimated economic growth at 2.8% compared to 7.1% in the South Asia Region (Wignaraja *et al*., 2019).

Uganda is blessed with a range of energy resources for example hydro, biomass, solar, geothermal, peat and fossil fuels that fairly span across the country's regions (Kabasingwa, 2019). According to Mukwaya (2016), energy is very important in the country, evidenced in the National development plan 2010/11 – 2014-15 in which it is one of the eight primary growth

sectors. Nevertheless, the country is one of the countries with the least access to advanced energy services characterized by low access to electricity, with a very low connectivity of only 28%; far below the Sub-Saharan Africa average of 45% in 2017 (du Can *et al*., 2018). More so, electricity consumption per capita is estimated to be 100kWh - one of the lowest globally. For these reasons, the country depends on biomass-based energy sources that account for up to 95% of the total domestic energy needs (Bamwesigye *et al*., 2020). Furthermore, biomass is utilized in a highly inefficient way, resulting in unsustainable exploitation of Uganda's forest resources (Wassie & Adaramola, 2019). The pressure on her forest resources is even worsened by the rapid population growth, estimated at 3.32% per annum (Obubu *et al*., 2022), one of the highest globally. Several researchers, including Riti & Shu (2016); Arega & Tadesse (2017) agree that high reliance on forest reserves disrupts carbon sinks, resulting into adverse effects of climate change.

In the Ugandan context, clean energy is associated with either the use of improved biomass cook stoves (ICS) or a shift to clean cooking fuels like liquefied petroleum gas (LPG), biogas or ethanol (Lietaer *et al*., 2019). Government reports affirm that the use of clean fuels such as biogas, liquefied petroleum gas and electricity for domestic chores like cooking and lighting is still very insignificant (Wassie & Adaramola, 2019), more so for households in the rural areas where up to 75.64% of country's population reside (World Bank, 2021). This is owed to unfavorable economic conditions such as relatively high prices, low demand and unreliable supply (Lietaer *et al*., 2019). Whereas the development and implementation of renewable energy options has contributed to reducing energy poverty in the country, many rural households are still lagging behind in terms of uptake of these alternative energy sources. Cooking is still done under unfriendly conditions and many of the cooking places are tainted with soot (Namugenyi *et*

al., 2022). This is a threat to household health, especially for children and women that usually have high exposure to smoke filled kitchens (Namugenyi *et al*., 2022).

Domestic biogas systems are alternative renewable energy sources encouraged for rural households with access to sufficient suitable organic feedstock such as animal wastes (Clemens *et al*., 2018). They are sustainable, and demonstrate potential to reduce rural household's reliance on firewood and fossil fuels that are expensive (Walekhwa *et al*., 2009). As a fuel, biogas is different from other renewable energy sources. It is a more sustainable and effective greener fuel with the ability to substitute fossil fuels as the primary provision of energy for heat, cooking fuel and light. Obaideen *et al*., (2022) asserts that biogas directly contributes to achievement of 12 out of the 17 SDGs owed to its ability to improve human health, advance gender balance, increase crop productivity, reduce climate change, improve waste management, and create jobs. At household level, the technology has been promoted using the family-sized digesters with three basic designs: floating drum, tubular and fixed dome (Kandpal *et al*., 1991). In developing countries, the fixed dome is the most preferred (Mwirigi *et al*., 2014) owed to its affordability and durability (Sasse *et al*., 1991).

Biogas has been successfully used as fuel for electricity generation in countries like Thailand (Aggarangsi *et al*., 2013) and Malaysia (Hashim & Ho, 2011) and for heat generation and cooking in China (Chen *et al*., 2012), India (Raha *et al*., 2014) and Bangladesh (Kabir *et al*., 2012). Whereas there are more barriers to biogas use in Sub Saharan Africa, countries like South Africa (Mutungwazi *et al*., 2018). Ghana, Rwanda and Tanzania (Amigun *et al*., 2012) have successfully produced biogas from large scale institutional plants using similar technologies as in developed countries.

In Uganda, cow dung is most prevalent feedstock used in the generation of domestic biogas. Cow dung is used in up to 97% of the country's digesters due to the fact that cows create more waste than any other domestic animal (Lutaaya, 2013). There has been an increase in the number of cattle from 11.4 million in 2008 to 12.1 million in 2018 (Magunda, 2020) and a shift to ranching and semi-intensive management systems that currently account for 30% and 25% of the total herd respectively. (Hernández-Castellano *et al*., 2019), augmenting the potential for domestic biogas systems. Promotion of Biogas as an alternative source of energy has been done by both the government and Non-Government Organizations (NGOs) mostly using the free of cost and free of service business models that entail free donation and servicing of domestic biogas systems *(Clemens et al*., 2018).

In their research, Clemens *et a*l., (2018); Kabyanga *et al*., (2018); Okello *et al*., (2013) discovered that using commercial tactics to encourage biogas adoption might sustainably improve access to clean energy in poor nations. However, most commercialization initiatives have met with poor public opinion, which is thought to be attributable to preconceptions that impact willingness to pay for household biogas systems. In this context, the study attempted to investigate families' perceptions and willingness to pay for domestic biogas systems.

1.2 Statement of the problem

Since the 1950s, the Ugandan government and private sector have actively developed programs and policies to support and install biogas systems in rural areas (Tumusiime *et al*., 2019). These programs have focused on domestic biogas systems tailored for rural areas, mainly the fixed dome digesters (Walekhwa *et al*., 2009). With efforts from organizations such as Heifer International, Caritas, GIZ, and Send a Cow Uganda among others which are leading in the

implementation of biogas technology in Uganda, the program is yet to reach all rural households. Despite the promotion of Biogas systems by these agencies, only 5800 systems had been established in Uganda by 2017, contributing to 25.6% of the prior established target (Tumusiime *et al*., 2019). Although relevant studies have been conducted to explain the low uptake of the technology, there is limited empirical evidence on factors associated with perception and willingness to pay for domestic biogas systems in Uganda (Kabyanga *et al*., 2018). The only known evidence of WTP study in Uganda was conducted among farmers in the central region and focused on the flexible balloon digester design (Kabyanga *et al*., 2018), with no evidence on farmers in other regions like northern Uganda. To fill this knowledge gap, this study sought to establish the factors that are associated with perceptions and willingness to pay for fixed dome domestic biogas systems by farmers in Gulu and Kitgum districts in Northern Uganda.

1.3 Objectives of the Study

1.3.1 General objective

The study generally aimed at establishing the factors influencing perception and willingness to pay for domestic biogas systems among small-holder farmers in Gulu and Kitgum districts, Northern Uganda.

1.3.2 Specific objectives

Specifically, the study sought to:

1. Characterize cattle producing households by their socio-economic status

2. Determine factors associated with households' perception on use of domestic biogas systems for domestic energy application.
3. Ascertain the determinants of households' willingness to pay for domestic biogas systems

1.4 Research questions

The following research questions were answered:

1. What are the socio-demographic characteristics of cattle producing households in northern Uganda?
2. What are the drivers of household perception of domestic biogas systems in northern Uganda?
3. What are the factors that influencing household willingness to pay for domestic biogas systems?

1.5 Conceptual Framework

The conceptual framework shows the relationship between key study variables. The Technology Acceptance Model postulates that the motivation of users of a given technology are centered on the dynamics of behavioral intention of the user and attitude towards the technology and two internal factors which are perceived usefulness and perceived ease of use. Davis defined the perceived usefulness as the potential user subjective probability that using a specific technology will increase the consumer satisfaction and the perceived ease of use as the extent to which the potential user expects the technology to be free of effort (Sari et al., 2022). According to the model, behavioral intention defines the actual use of a given technological system and consequently determines the technology acceptance. Attitude towards use and perceived usefulness together influences the behavioral intention.

Indirectly, behavioral intention is affected by the perceived ease of use while attitude towards use is directly influenced by both perceived ease of use and perceived usefulness. In turn perceived ease of use is directly influenced by perceived usefulness. Further, the technology acceptance model conceived that perceived ease of use and perceived usefulness are determined by external variables. Therefore, there is a mediation between perceived ease of use and perceived usefulness, which results in the external variables influence of the users' attitude and perception towards the technology.

Subsequently, respondents with a positive perception towards biogas technology are most likely to be willing to pay more money than those with negative perceptions towards the technology.

CONCEPTUAL FRAMEWORK

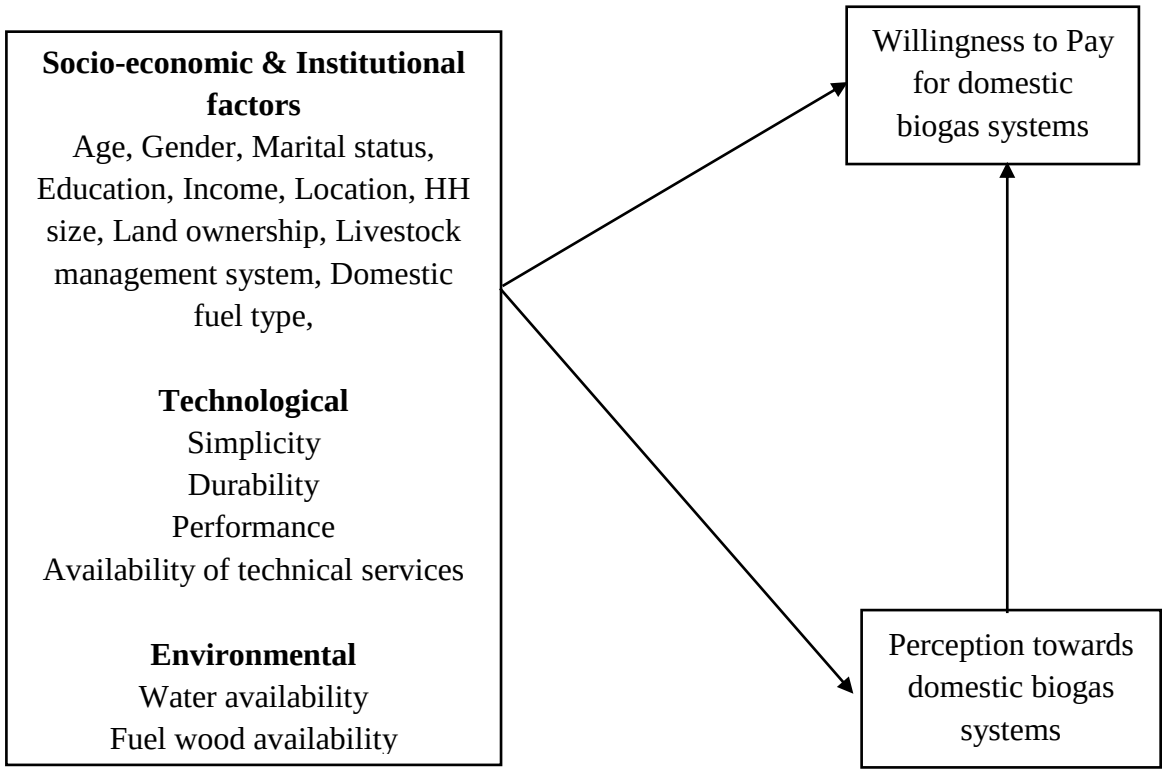


Figure 1: A conceptual framework showing the factors affecting households' perceptions and willingness to pay for domestic biogas systems

Source: Adapted and modified from Munene (2006)

1.6 Scope of the Study

The scope of this study was divided into three parts: Time, contextual and geographical. The time scope was between December 2021 and October 2022. Geographically, the study was limited to the districts of Gulu and Kitgum in northern Uganda. Contextually, the study focused on factors that influence household's perception and WTP for domestic biogas systems. Information on perception as well as their WTP were captured.

1.7 Justification of the study

This study investigated the factors influencing perceptions and WTP for domestic biogas systems. Cognizant that sustainable uptake of a given technology requires that the factors that cause individuals to choose, adopt, or reject a particular innovation are precisely understood, the study aimed to provide insights into factors that influence critical energy related decision making at household level. The estimation of WTP for domestic biogas systems is paramount in determining the appropriate pricing mechanisms with respect to the attributes of the energy source. Furthermore, the research findings are of paramount importance to policy makers, scholars, non-government agencies and private sector actors working towards sustainably scaling up the uptake of renewable energy sources in developing countries.

CHAPTER TWO: LITERATURE REVIEW

2.1 The energy sector in Uganda

Uganda has experienced rapid economic growth, and like any other developing country, the demand for energy is at an increase, exceeding supply (Gustavsson & Broad, 2015). Energy poverty is reported to be a bottleneck to economic advancement and social transformation of the country (Mukwaya, 2016). Currently, the country has twelve power generation plants with an average capacity of 65.1 MW. Kiira hydropower station has the highest capacity of 200MW meanwhile Nyagak II hydro plant has the least capacity of about 3.5MW. Furthermore, there are about seven hydro projects that are yet to be completed. These are sufficient to deliver an average of 266.1MW, with the Karuma hydro project having the highest potential of 600MW and the Nyagak III having the least capacity of about 4.4 MW (Twaha *et al*., 2016).

To increase the consumption of solar energy, the government has built two 10MW solar power plants, the largest in East Africa, in its eastern districts of Soroti and Tororo at a cost of USD 19 million and USD 19.6 million respectively that are estimated to connect electricity to around 75,838 (40,000 in Soroti and 35,838 in Tororo) residents (Twaha *et al*., 2016). It is Uganda's first grid-connected solar plants as the country looks to raise power generation capacity to 1,500MW by 2020, from the current 850MW. The power plants have the potential to increase their net output capacity by further 20MW of solar energy (Twaha *et al*., 2016). Rural Electrification Agency (REA) estimates that so far over 30,000 solar PV systems have already been installed to in rural areas in the country and still there are huge unexploited solar energy resources.

Despite the country's vast hydropower power and solar potential, the current utilization is still below optimum (Twaha *et al*., 2016). The demand for electricity is 260MW during the day and rises to 350MW in the evening. The rise in the evening is owed to domestic activities of homes, which account for the majority of most of UMEME's clientele (Adeyemi & Asere, 2014).

2.2 Biogas Potential in Uganda

The use of clean energy such as biogas, liquefied petroleum gas (LPG), and electricity for domestic purposes such as cooking and lighting is still not popular among Ugandan farming households (Behera *et al*., 2016) with the country having immense reliance on low-grade solid biomass fuels like firewood and charcoal that account for up to 94% of the total energy consumption (Namugenyi *et al*., 2022). Furthermore, kerosene is still the principal source of lighting for more than half of rural families and 16% of urban households (Walekhwa *et al.*, 2009).

Uganda is rich in biodegradable substrates that may be utilized as feedstock for biogas production. Animal feces, municipal garbage, human excreta, and food remnants are examples. According to Owusu & Banadda (2017), the most often utilized substrate by households is animal manure from cattle, pigs, sheep, goats, and poultry. With an average potential of 1,300 m^3, equivalent to 7 million MWh and 25.17 PJ of electricity, biogas can fulfill 40% of Uganda's primary energy supply. According to these figures, Uganda has the capacity to create up to 1 billion cubic meters of biogas per year, which is comparable to a 1000MWh hydropower plant (Pandey & Bajgain, 2007; Namugenyi *et al*., 2022).

Walekhwa *et al*., (2009) further asserts that Uganda has the ability to generate 1740 Mt of energy from animal waste at a 30% recoverable rate. If all of the generated energy is used, it will result in better health, economic, and environmental results for households (Peipert *et al*., 2008). According to Clemens *et al*., (2018), the majority of biogas-producing families in Uganda create extra biogas, while some produce less than their full capacity. This suggests that the productivity of biogas energy in Uganda has a great potential for realizing the bioenergy transition.

2.3 Biogas plant designs in Uganda

In Uganda, the majority of digesters are small-scale, often known as family-sized digesters (Kandpal *et al*., 1991) with three primary designs: floating drum, tubular and fixed dome (Ocwieja, 2010). Because the fixed dome digester is inexpensive and long-lasting durable (Sasse *et al*., 1991), it is the most popular biogas plant design in Uganda (Mwirigi *et al*., 2014). The majority of domestic biogas systems promoted in Uganda feature digester volumes of 8, 12 or 16 m^3 (Walekhwa *et al*., 2009). There are also a few institutional and community biogas plants with capacities of 30 or 50 m^3 (Walekhwa *et al*., 2009). Currently, cow dung is the most common substrate for biogas digesters in the nation (Walekhwa *et al*., 2009). However, a variety of possible feedstocks, such as agro-industrial leftovers, municipal solid wastes and waste waters, forestry by-products and residues, agricultural residues, and domestic food wastes, might be employed (Walekhwa *et al*., 2009).

2.4 Households' Perceptions towards domestic biogas systems

Perception is described as the mechanisms by which individuals make meaning of technology (Çeliköz *et al*., 2019), taking into account the utility, safety, and compatibility of the technology,

as well as the repercussions inform of danger or expenditure connected with embracing the technology (Zahari & Esa, 2018). It is developed by one's experiences and determines the trajectory of one's reactions (Lambrinou *et al*., 2009).

Perception is an important determinant of pro-environmental behavior, such as renewable energy adoption (Smiley *et al*., 2022). Perceptions of renewable energy sources are typically complicated and diverse, and they are influenced by contextual, psychological, and personal aspects such as the technology's nature and scale. Limmeechokchai & Chawana, (2007) underscored the need of investigating households' perceptions towards renewable energy in order to guide policies targeted at lowering obstacles to adoption of these energy options.

From a consumer's point of view, Malla & Timilsina (2014) stated that a reduction in the rate of air pollution ascribed to a specific fuel, time saved from fuel collection, cost savings, aesthetic advantages, and an enhancement in social status are major qualities that impact customer opinion. According to Ruiz-Mercado *et al*., (2011) perception is also impacted by monetarization of better fuel, fuel speed of cooking, convenience, compatibility with local cooking customs, modernity status, and pollution-related concerns.

2.5 Willingness to Pay

2.5.1 Concept of Willingness to Pay

Willingness to Pay (WTP), by definition is the greatest price or quantity of money that a consumer is prepared to spend to purchase an item or service or to equalize a utility adjustment (Owusu & Owusu, 2013). It is based on the mainstream consumer behavior theory (Bishop & Heberlein, 1979; Hoehn & Randall, 1987) which contends that the greatest amount of money a

customer is prepared to spend for an item is an indicator of the commodity's worth to the consumer.

2.5.2 Empirical research on consumers' WTP

Different methodologies have been utilized in empirical investigations of consumers' WTP. The stated preference method which combines the choice experiment (conjoint analysis and choice modeling), and contingent valuation method which are the most extensively used economic valuation methods to elicit consumer's WTP for a good or service.

In choice experiments, respondents are asked to assess combinations of qualities and related levels in order to select their favourite option from a collection of alternatives with defined attributes (Abdullah *et al*., 2009). In contrast, contingent valuation requires explicitly asking respondents if they are prepared to pay for a certain commodity or service. The contingent valuation approach elicits values for defined products by giving respondents with a description of a proposed hypothetical scenario and asking them to express their maximal WTP to enjoy a positive shift or change (Lusk & Hudson, 2004; Balana *et al*., 2013).

Surveys using the Contingent Valuation Method (CVM) produce significant results when properly anchored in a paradigm of consumer maximization (Hanemann & Kanninen 1996). As a result, it is anticipated that customers would pick the choice that provides them with the greatest utility given the budget constraint. (Zhang *et al*., 2010).

2.5.3 WTP for renewable energy technology

Household WTP is based on an examination of demographic characteristics as influencers of consumer preferences rather than product qualities, which may be imprecise estimations from which to construct a full market framework for biogas technology. Several studies have been conducted, for example, (Aini & Ling, 2013) analyzed factors affecting household willingness to pay for renewable energy technology (RET) examined factors influencing willingness to pay for renewable energy technology (RET) among households in Eastern Malaysia and discovered that the majority of the households expressed concern for the environment and a positive attitude towards RETs. Age and household understanding of the technology influenced willingness to pay for RETs positively and significantly, however gender had no effect on the choice made by the household. Osiolo (2017) employed the CVM in Kenya to determine the drivers of WTP for enhanced energy and discovered that income, type of housing, level of education, gender, price, and location all affected WTP. In Ghana, a CVM was utilized to identify the factors that affected households' WTP for better energy supply. An econometric analysis applying the ordered probit estimation revealed that WTP was highly impacted by household income, gender, household size, and level of education (Twerefou, 2014).

For biogas, Jules & Navalona, (2022) used the CVM to investigate farmers WTP for the technology in Madagascar. Results showed that the cost of domestic energy for cooking, number of dairy cows, on farm income, off farm income and experience borrowing money form a micro credit institution positively and significantly influenced WTP whereas land area and utilization of manure negatively influenced WTP for the digesters.

Kabyanga *et al*., (2018), investigated the WTP for domestic biogas systems in central Uganda and found that household size, education level, gender and age of the household head, number of livestock owned, total land area owned and a household's perception on technology had a significant impact on the WTP. They however focused on the imported flexible balloon digester and his study sample included houses that were already using the system and was limited to only central Uganda.

2.5.4 WTP amount

Nkunzimana *et al*., (2014) evaluated the consumer's WTP for the development of biogas energy technologies in the Gihanga district of Burundi. The findings indicate that the amount a household is willing to pay per month increases with household size, whether the household has a thorough understanding of climate change mitigation, whether consumers use candles for lighting, household's income, and the education level of the head of the household. Similarly, Zografakis *et al*., (2010) employed the contingent valuation technique to determine citizens' acceptance and WTP for renewable energy sources in Crete. The results of this study demonstrated that the WTP amount increased when household income, household size, energy information, and climate change awareness increased.

2.5.5 Analysis of WTP

From literature, several econometric models have been used to analyze the participation behavior among farmers. These models have been applied depending on the nature of data available and the question at hand (Mwema & Crewett, 2019). In particular, the probit and logistic regression models have been used to examine the dichotomous issue of the probability of adopting a new agricultural innovation or not in various studies (Audu & Aye, 2014; Khonje et al., 2015;

Mainimo et al., 2022; Mango et al., 2018; Ngango & Hong, 2021). With regards to investigating whether the farmer is willing to to pay for a domestic biogas system or not and if yes, determine the amount of money the farmer is willing to pay for the domestic biogas system, the use of probit, logit, and Tobit models were not appropriate.

Therefore, this study used a double-hurdle model proposed by Cragg (1971) for this purpose (Lin & Schmidy, 1984). The double-hurdle model embodies two stages, the first hurdle is the decision of whether or not to pay for the domestic biogas system (participation decision) and the second hurdle is the intensity decision which involves the estimation of amount of money farmers are willing to pay. According to Engel & Moffatt, (2014), the double-hurdle model accommodates two equations as a combined probit and Tobit estimator.

Based on the preceding review, perception and WTP impact the adoption of renewable energy technology. However, to the best of the researcher's knowledge, no published work on households' perceptions and willingness to pay for domestic biogas systems in Northern Uganda exists.

CHAPTER THREE: METHODOLOGY

3.1 Study Area

This study was carried out in Gulu and Kitgum districts, Northern Uganda (figure 2). The districts were purposively selected because they are key implementation areas for the Green Energy and Nutrition project which is promoting sustainable biogas uptake. Gulu district is bordered by Lamwo district to the North, Omoro district to the south, Amuru district to the west, Pader district to the East, and Nwoya district to the southwest. The district is located at 02 450 N, 32 0000 E and approximately 330 km North of Kampala; Uganda's capital city (UBOS, 2013). The estimated population of the Gulu district is 125,307 with 48.6% and 51.4% Male and female composition respectively, and an annual population growth rate of 2.8% (UBOS, 2016a).

Kitgum District, on the other hand, is located between Longitude 320E and 340E and Latitude 020N and 040 N. The district is bordered by the Republic of Southern Sudan to the north, Karenga District to the east, Kotido District to the South East, Agago District to the South, Pader District to the Southwest, and Lamwo District to the Northwest. Kitgum District has a total population of 204,012 with 48.3% Male and 51.7% Female and an annual growth rate of 1.69% (UBOS, 2016a).

The climate of the study area is tropical and with 2 rainy seasons, the first rains between April and June and the second in August and October. The mean precipitation is 1250 mm and the average temperature is between 20-30^{o}C. The main economic activity is the growing of crops mainly millet, cassava, and sesame. About 56% of the households are engaged in livestock production with 14% owning cattle (Ekesa *et al*., 2022). The primary source of domestic fuel is traditional biomass with the majority of households using firewood while others use charcoal.

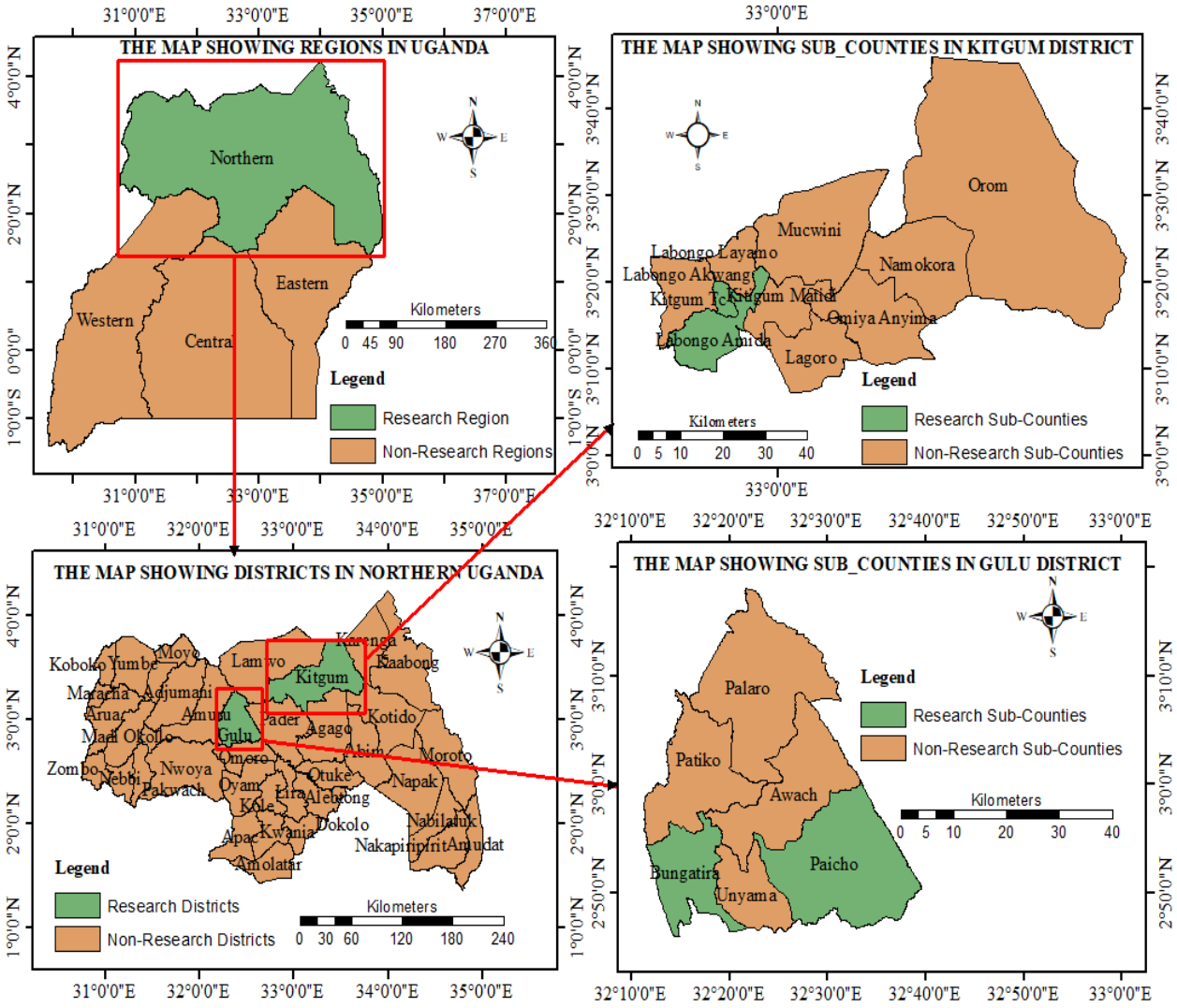


Figure 2: Map showing study area

3.2 Research design

A cross-sectional survey design was used to collect quantitative data from households to explore the factors associated with perceptions and willingness to pay for domestic biogas systems. The research design was adopted because it is time-saving, inexpensive, does not require follow-up, and is good for inference to the whole population (Levin, 2006).

3.3 Sample size determination and sampling procedure

3.3.1 Sample size determination

The sample size for the study was determined following equation (1) as described by Cochran (1977).

$$\text{"Sample size, n} = \frac{Z^2 P(1-p)}{e^2} \quad (1)$$

"Where n is the required sample size, Z is the confidence level at 95% (standard value of 1.96), P is the estimated percentage of cattle-keeping households in the Acholi sub-region; 14% (Ekesa *et al*., 2022), e = Margin of error at 5% (standard value of 0.05)." Using the above formula:

$$Sample\ size, n = \frac{0.96^2 * 0.14 * 0.86}{0.05^2} = 185$$

Additional 65 respondents, equivalent to 35% of the computed sample size, were added to reduce bias that could have arisen from respondents who were absent during the interview as well as cases of non-response, either at the beginning or during the data collection exercise (Wawire *et al*., 2017). As a result, a total of 250 respondents, 120 from Gulu and 130 from Kitgum, took part in the survey. The greater number of participants from Kitgum district was owing to the fact that there were more cattle farming households in Kitgum than in Gulu.

3.3.2 Sampling procedure

The study focused on households in Gulu and Kitgum District, Northern Uganda. The multi-stage sampling procedure was used in the selection of a representative sample. The first stage involved purposively selecting Gulu and Kitgum districts. These were chosen because of the relatively high number of projects aimed at increasing biogas uptake in these districts. In stage

two, two sub-counties in each of the districts were purposively selected Bungatira and Paicho, from Gulu distrct, and Kitgum municipality and Labongo Amida in Kitgum district, based on the predominance of biogas plants and livestock farming households. In the third stage, 250 households engaged in cattle rearing were purposively selected to participate in the study.

3.4 Data collection

3.4.1 Data collection instrument

Data was collected using questionnaires (Appendix 1) that were administered through face-to-face interviews. Prior to actual data collection, the questionnaire was pretested on 20 cattle producers in Omoro District to evaluate the appropriateness of the design, coherence, and relevance of the questions. The pre-test informed questionnaire modification to precisely capture the relevant information related to the problem under study. The questionnaire comprised both close-ended and open-ended questions. It collected data on demographic and socio-economic characteristics of cattle producers, perceptions, and willingness to pay (WTP) for domestic biogas systems.

For specific objective one, the pretested and structured questionnaire focused on socio-demographic characteristics such as age, sex, education, livestock ownership, livestock management systems, occupation, income, domestic fuel type, and quantity used. For specific objective two, perception questions on the attributes of domestic biogas systems were set on a five-point Likert scale ranging from “Strongly disagree”, “Disagree”, “Undecided”, “Agree” to “Strongly agree”. These attributes included installation costs, maintenance costs, ease to understand and operate, environmental protection, health concern, and time-saving. The

respondents were required to rate the statements on a five-point Likert scale based on the extent to which they agreed or disagreed with the statements. This scale is precise and easy to comprehend thus helping respondents to clearly distinguish between alternatives (Senger et al., 2017).

For specific objective three, the Contingent Valuation Method was used to acquire data on willingness to pay. This method was adopted considering that the study was determining willingness to pay for a commodity (domestic biogas system) that is not regularly sold in the market. Respondents were first asked if they had ever heard of domestic biogas systems, and then hypothetical information on the uniqueness of the systems was presented to the respondents, who were then asked to answer a willingness to pay question with two levels. (1) Are you willing to pay? (2) If yes, how much are you willing to pay?

3.4.2 Data collection procedure

Four research assistants with proficiency in both English and Acholi language was trained on the content of the questionnaire and how to conduct the face-to-face interview. The researcher obtained permission from the district production and marketing offices of Gulu and Kitgum districts, as well as from the Senior Assistant Secretaries (SAS) of the participating sub-counties, to conduct the study in their areas of jurisdiction. With assistance from community-based local guides, research assistants identified the participating households and administered the face-to-face interviews in Acholi language while recording the responses in English. Acholi language was used during interviews because it is the local dialect of the study area and most of the target respondents are fluent in the language.

3.5 Data quality control

To guarantee content validity, questionnaire items were developed with the assistance of research supervisors to capture data on the problem under investigation. A pre-test of the translated questionnaire was carried out on 20 respondents from the Omoro district, which was outside of the research region. The sequence of questions and replies was evaluated during the pre-test to check if they accurately responded to the study's specific objectives. Following the pre-test, the questionnaire was revised to increase the content reliability (Uijen *et al*., 2011).

3.6 Data analysis

To guarantee completeness, consistency, and accuracy, data was entered and cleaned. Coding was done to arrange and categorize data into thematic areas of the study (Amin 2005).

SPSS and STATA software version 17 were used to analyze the data. Correlation analysis (Pearson) was done before running each regression model to identify strongly associated pairings of independent variables (correlation coefficient > 0.7) (Dormann *et al*., 2013). Study variables that were highly correlated were not used in the same model at the same time. A heteroscedasticity test was performed on the variables to see if there was a sequence of conditional variances that changed. Descriptive statistics for instance Mean, standard deviations, and frequencies were computed.

3.6.1 Objective 1: To characterize cattle-producing households

Descriptive statistics were used to analyze the socio-economic characteristics of the respondents. Furthermore, study variables for Kitgum and Gulu were disaggregated and contrasted using bivariate analyses. T-tests were used to compare means of each of the continuous variables

including age of household head, house hold size, number of children, number engaged in farming, education level of house hold head, income, and number of cattle to see if a significant difference existed between the two groups of Gulu and Kitgum. The categorical variables including gender of household head, location of household, marital status and occupation were analyzed using the chi square. This was done to establish if a significant association existed among the categorical variables of the cattle producing households in Gulu and Kitgum districts.

3.6.2 Objective 2: To assess the determinants of households' perception of domestic biogas systems

In order to accomplish this objective, perception scores were calculated by adding the values obtained in each question. Perception scores were calculated as a proportion of total points. Using the median score, a cut-off point was determined (Dinegde & Xuying, 2017), and the perception variable became binary, with positive and negative perception for scores above and below the cut-off point, respectively.

The binary logit model was used to assess respondents' perceptions of domestic biogas systems. The choice of the model was motivated by the fact that it allows for analysis of decisions limited to a maximum of only two choices. The binary logistic regression model is presented as in equation (2).

$$Y(i(1,0)) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ldots + \beta_n X_n + \mu \quad (2)$$

Where: Y_i= Perception, a binary response variable equal to 1 for positive perception and 0 for negative perception, X_1 to X_n = Independent variables, α = Regression constant, β = Regression coefficient, μ = Error term. The variables used in the binary logistic model are shown in Table 1.

Table 1: Description of variables used in the binary logistic model

Variable name	Apriori sign	Citations
Gender (1=male, 0=otherwise)	+/-	(Bain & Rice, 2006); (Getachew & Berhanu, 2013); (Tarhini *et al*., 2014); (Behera *et al*., 2016); (Li *et al*., 2016); (Namugenyi *et al*., 2022)
Location (1=rural, 0=otherwise)	+/-	(Walekhwa *et al*., 2009)
Marital status (1=married, 0=otherwise)	+	(Nnadi & Akwiwu, 2008); (Donye *et al*., 2012); (Chikezie *et al*., 2012); (Gezahegn *et al*., 2018)
Household Income (Ugandan shillings)	+	(Wawa, 2012); (Ntanos *et al*., 2018); (Geddafa *et al*., 2021)
Livestock management (1=free range, 0=otherwise)	-	(Mwirigi *et al*., 2009); (Bößner *et al*., 2019); (Aikhuele *et al*., 2020); (Fentie & Sime, 2022)
Water availability (1=yes, 0=otherwise)	+/-	(Wargert, 2009)
Participation in biogas project (1=yes, 0=otherwise)	+	(Kabyanga *et al*., 2018b)
Access to technicians (1=yes, 0=otherwise)	+	(Nasery, 2011); (Uhunamure, 2019); (Geddafa *et al*., 2021)
Age of household head (years)	-	(Getachew & Berhanu, 2013)
Access to enough waste (1=yes, 0=otherwise)	+	(GHU *et al*., 2013)

3.6.3 Objective 3: To ascertain the determinants of willingness to pay for domestic biogas systems

This objective was analyzed using the double hurdle model proposed by Cragg (1971). According to this model, households must pass two separate hurdles before they are observed with a positive level of consumption. The double model was used because it allows for independent analysis of the household's willingness to pay and the payment levels. In addition, it reduces the selection bias associated with sampling (Kong *et al*., 2014).

The double hurdle model embodies two stages; the first hurdle is the participation decision which was estimated using a binary probit model with the data collected in the first elicitation question on whether respondents were willing to pay for a domestic biogas system. The choice of this model was motivated by the fact that the dependent variable is dichotomous in nature (Kaplan & Venezky, 1994).

The probit model predicts the probability of whether an individual household was willing to pay for domestic biogas systems or not. The equation is specified as below:

$$pr\ (Y_i\ = 1/\ X_i, \alpha)\ =\ \phi\ (h\ (X_i, \alpha)\ +\ \varepsilon i \quad (3)$$

"Where pr is the probability of willingness to pay, Yi is an indicator variable equal to unity for households that were willing to pay for domestic biogas systems and zero otherwise. ϕ is the standard normal cumulative distribution function; Xi is a vector of determinants of willingness to pay. α is the vector of coefficients to be estimated and εi is the error term assumed to be normally distributed with a mean of zero and a variance σ2." The latent variable Yi (equation 4) takes the value 1 if the marginal utility the ith household gets from choosing to pay and use domestic biogas systems is greater than zero and zero otherwise (equations 5 and 6). This is shown as follows:

$$Yi\ *=\ Xi\ +\ \mu i \quad (4)$$

Where $Y*$ is the latent level of utility the household got from choosing to pay and use domestic biogas systems, μi ~ N (0, 1) and,

$$Yi\ =\ 1\ if\ Y\ *>\ 0 \quad (5)$$

$$Yi\ =\ 0\ if\ Y\ *\leq\ 0 \quad (6)$$

Y_i is the observed dichotomous variable Willingness to Pay (WTP)

In the outcome model of the second hurdle, a vector of Inverse Mills Ratio (estimated error) was generated from parameter estimates and used to correct for potential selection bias. After constructing the Inverse Mills Ratio (IMR), the payment level for individual households that were willing to pay for domestic biogas systems was then regressed on the explanatory variables and the vector of the IMR from the selection equation by the Tobit regression model. This regressor, also referred to as the Inverse Mills Ratio is computed as:

$$\Phi\ (h\ (Xi, \alpha\sim))\ (\varphi\ (Xi, \alpha\sim) \qquad (7)$$

In the first stage of deciding whether to pay for domestic biogas systems or not (Participation decision). This selection equation was specified as equation 8:

$$P\ (i\ (0,1))\ =\ \beta_0 X_0 + \beta_1 X_1\ +\ \beta_2 X_2\ + \cdots \ldots \ldots \ldots \ldots\ \beta_n X_n\ +\ e \qquad (8)$$

"Where Willingness- to- pay (WTP) is denoted by 1 and Unwillingness-to- pay by 0, β_0 is a constant, β_1 … n are parameters to be estimated, X_1 …. n are vectors of the explanatory variables."

In the second stage of the analysis, the outcome equation was estimated using a Tobit regression model to further investigate the factors influencing payment levels for the domestic biogas systems. The equation is as follows:

$$(Y * i)\ =\ \beta_0\ +\ \beta_1 X_1\ \ +\ \beta_2 X_2\ \ + \cdots \ldots \ldots \ldots \ldots\ \beta_n X_n\ \ +\ \delta\lambda\ +\ e \qquad (9)$$

"Where Y denotes payment level (UGX), β_0 is a constant, $\beta_1 \ldots . n$ are parameters estimated, and X_1 …. n are vectors of the explanatory variables."

Table 2 Description of variables used in the double hurdle model

Variable name	Apriori sign	Citations
Access to technician	+	(Nevzorova & Kutcherov, 2019); (Mugo & Gathea, 2010); (Mukumba *et al*., 2016); (Mukisa *et al*., 2022)
Gender (1=male, 0=otherwise)	+/-	(Kabir *et al*., 2013); (Aini & Goh Mang Ling, 2013); (Vaidy, 2019); (Atinkut *et al*., 2020); (Twerefou, 2014)
Water availability	+	(Mwakaje, 2008); (Malla *et al*., 2011)
Paraffin Use	+/-	(Bhandari & Jana, 2010)
Distance to firewood source	+	(Ferrer *et al*., 2011); (Kasap *et al*., 2012); (Guta, 2014); (Mengistu *et al*., 2016); (Mukisa *et al*., 2022)
Tropical livestock unit	+	(Walekhwa *et al*., 2009); Kabyanga *et al*. (2018a)
Participation in biogas project (1=yes. 0=otherwise)	+	(Amigun *et al*., 2012); (Sardianou & Genoudi, 2013); (Padi *et al*., 2015); (Hojnik *et al*., 2021)
Perception score	+	(Ngcobo *et al*., 2022)
Location (1=rural, 0=otherwise)	+/-	(Walekhwa *et al*., 2009)

3.7 Ethical Consideration

The study adhered to all legal and ethical requirements regulating research in Uganda. The researcher acquired ethical approval from the Gulu University Research Ethics Committee (GUREC) before commencing the study. Approval was also sought from the Chief Administrative Officer (CAO) to carry out the study in each of the 2 districts. Enumerators received consent from respondents at the start of each interview session (Appendix 2), and participation in the study was entirely voluntary. The research ensured that human rights were fully respected and that all respondents and research assistants that participated were in healthy and in good conditions. Furthermore, proper referencing was done to avoid plagiarism and fraud and the findings of the research would be disseminated and published for the benefit of an extensive range of stakeholders.

CHAPTER FOUR: RESULTS

4.1 Socio-economic characteristics of cattle producers

The socioeconomic characteristics of households engaged in cattle production are presented in Tables 3 and 4. Of the respondents that participated in the study, 53.6% were from Kitgum whereas 46.4% were from Gulu. The respondents' socioeconomic characteristics were further subdivided into continuous and categorical variables. The continuous variables considered were the age of the household head in years, household size in numbers, number of children, education level in years, cattle owned in numbers, household income in Uganda shillings, and land size in acres. On the other hand, the categorical variables considered included the sex of the respondent, sex of the household head, location of the household, marital status, Occupation, and main source of household income.

According to Table 3, the mean difference of continuous socioeconomic characteristics showed that household size ($p < 0.01$), number of adults in the household ($p < 0.01$), number engaged in farming ($p < 0.05$), education level of household head ($p < 0.01$), household income ($p < 0.01$) and number of cattle ($p < 0.01$) had statistically significant differences between cattle producing households in Kitgum and Gulu. The rest of the socio-economic factors which included age of respondent, age of household head, and number of children, were not significantly different for the two districts.

The overall mean household size was found to be six (6) members. The mean household size for Kitgum and Gulu were seven (7) and six (6) respectively. Household size in the 2 districts was statistically significant at ($p < 0.01$) with households in Kitgum being larger than those in Gulu.

On average, Households comprised of three (3) adults with households in Kitgum having significantly higher number of adults at ($p < 0.01$). On average, each household had three (3) engage in farming activities at ($p < 0.05$). In Kitgum, household heads spent significantly higher number of years in education than their counterparts in Gulu at ($p < 0.01$). Overall, the average years of education that respondents took in school was found to be nine (9). The mean number of cattle per household was four (4), with households in Kitgum reporting larger herds than those in Gulu at ($p < 0.01$). The household income for the two districts was statistically significant at ($p < 0.01$) with households in Kitgum reporting higher incomes than their counterparts in Gulu. The mean age of the household head was 43.35 years. The age of the household head was almost the same in Kitgum and Gulu with no statistical significance. Similarly, the age of the respondent and number of children in the household was not statistically significant.

Table 3: T- test for equality of means for the continuous variables

Variable	Mean (SD)			Mean difference	t-value	Sig.
	Overall (n=250)	Gulu (n=116)	Kitgum (n=134)			
Age of Respondent	38.46(13.34)	38.81(14.20)	38.15(12.58)	0.653	0.385	0.700
Age of HH Head	43.38(12.60)	42.88(13.29)	43.81(11.98)	0.925	-0.578	0.563
Household size	6.28(3.30)	5.61(2.31)	6.85 (3.87)	1.238	-3.007***	0.002
Number of children	3.12(1.95)	2.91(1.89)	3.30(1.98)	0.392	-1.590	0.113
Number of Adults	3.07 (1.67)	2.70(1.46)	3.38(1.76)	0.681	-3.287***	0.001
Number engaged in farming	2.73(1.44)	2.50(1.05)	2.92(1.67)	0.425	-2.356**	0.019
Education level of HH Head	8.79(4.34)	7.56(4.23)	9.85(4.15)	2.290	-4.309***	0.000
HH income	540,636 (479,326)	494,033 (535,414)	580,980 (422,772)	86,947	-1.433	0.184
Number of cattle	4.46 (4.61)	3.58(2.74)	4.70(3.08)	1.119	2.926***	0.0038

Source: Field survey, (2022); Number of respondents =250

Table 4 showed that over three-quarters (76%) of the households were male-headed. Results from the chi-square analysis revealed that the gender of the household head was statistically significant ($p < 0.01$) indicating an association in the gender of the household head between

Kitgum (82.84% male-headed) and Gulu (68.10% male-headed). Most of the respondents (68%) were married. As per the chi-square results, marital status was statistically significant ($p < 0.05$) which implied that there was a significant association between marital status in the two districts.

Concerning the location of the household, 67.6% of the households that participated in the study were from rural areas while 32.4% were from urban areas. In Gulu, 79.3% were from rural areas and 20.69% were from urban areas. On the other hand, 57% of the households in Kitgum were located in rural areas whereas 42.54% were from urban areas. Chi-square analysis revealed that the location of the household was statistically significant ($p < 0.01$), which implied that there is an association in the location of households between Gulu and Kitgum districts. In terms of occupation, most of the respondents are not skilled accounting for 88.7% and 66.4% in Gulu and Kitgum respectively. The ($p < 0.01$) indicates an association in occupation between the two districts.

Table 4: Chi-Square Analysis of Cattle producing Households in Northern Uganda

		Frequency (Percentage)				
Variable	**Category**	**Gulu (n=116)**	**Kitgum (n=134)**	**Overall (N=250)**	χ^2	**Sig.**
HH Head Gender	Male	79(68.10)	111(82.84)	190 (76.00)	7.398***	0.007
	Female	37(31.90)	23(17.16)	60(24.00)		
Location	Rural	92(79.31)	77(57.46)	169(67.60)	13.550***	0.000
	Urban	24(20.69)	57(42.54)	81(32.40)		
Marital Status	Married	72(62.07)	98(73.13)	170(68.00)	3.498*	0.061
	Unmarried	44(37.93)	36 (26.87)	80(32.00)		
Occupation	Skilled	15 (12.93)	45 (33.58)	60 (24.00)	14.537***	0.000
	Otherwise	101 (87.67)	89 (66.42)	190 (76.00)		

Source: Field survey, (2022); Number of respondents =250.

4.2 Households' perception of domestic biogas systems

Taking the median score as the cutoff point, most of the farmers (52.8%) had a positive perception towards the biogas technology, whereas 42.2% had a negative perception towards the technology.

To determine the factors that influence a household's perception of domestic biogas systems, the binary logistic model was used. The Chi-square value of 0.2348 showed that the likelihood ratio statistics were highly significant ($p < 0.01$) suggesting that the model had strong explanatory power. The goodness of fit was insignificant which implied model fit. The Variance Inflation Factor (VIF) test had a mean VIF of 1.15. All the independent variables in the perception model had VIF values of less than 2 which is highly .acceptable (Mainimo et al., 2022) and meant that the level of multicollinearity was not severe (Lee, 2013). Seven variables were found to significantly influence perception. These are gender, household location, marital status, household income, livestock management system, access to adequate animal waste, and access to biogas technicians. Marginal effects of the binary logistic model results were estimated and used for interpretation of results given that the coefficients of the equation have no direct

interpretation and are only used to maximize the likelihood function. Positive statistically significant predictors of household's perceptions towards domestic biogas systems were marital status (Married) ($p < 0.05$), household income ($p < 0.05$), and livestock management system (Free Range) ($p < 0.05$) and Access to technician ($p < 0.01$); whereas gender of household head (Male) ($p < 0.05$), household location (rural) ($p < 0.01$), negatively and significantly influenced perception. However, water availability, participation in a biogas project, and age of household head did not influence households' perception of domestic biogas systems.

Table 5: Logit model results with binary effects

Variable	Coefficients	Marginal effect	p-values
Gender	-0.126(0.062)	-0.121(0.059) **	0.045
Location	-0.172(0.064)	-0.160(0.060) ***	0.008
Marital status	0.146(0.063)	0.133(0.060) **	0.022
Household Income	0.037(0.016)	0.045(0.023) **	0.024
Livestock management	-0.257(0.077)	-0.250(0.073) ***	0.001
Water availability	0.056(0.070)	0.057(0.066)	0.426
Participation in biogas project	0.092(0.083)	0.079(0.082)	0.269
Access to technicians	0.289(0.075)	0.279(0.071) ***	0.000
Age of household head	-0.100(0.084)	-0.095(0.082)	0.236
Access to enough waste	0.153(0.638)	0.137(0.061) **	0.017
Constant		0.2855(0.399)	
Log-likelihood		-141.524	
P-value		0.000	
Number of observations		250	
Pseudo R2		0.1814	
GOF – Pearson Chi2 (239) = 254.47; Prob > Chi2 = 0.2348			
Mean VIF	1.15		

Source: Field survey, (2022); Number of respondents =250

4.3 Determinants of Household Willingness to pay and payment levels for domestic biogas systems

4.3.1 Willingness to pay for domestic biogas systems

Table 6 showed that the majority of the households (90%) expressed a willingness to pay for domestic biogas systems. More so, most of these households (92.6%) were from urban areas.

Furthermore, households in urban areas reported higher WTP amounts that their counterparts in rural areas.

Table 6: Comparing WTP by location in Gulu and Kitgum districts

General WTP	Rural N=169	Urban N=81	Overall
	Frequency	**Frequency**	**Frequency**
Unwilling	19(11.2)	6(7.4)	25(10)
Willing	150(88.8)	75(92.6)	225(90)
Amount categories			
≤ 400,000	67 (44.7)	23 (30.7)	90 (36.0)
401,000 – 1,000,000	60 (40.0)	31 (41.3)	91 (40.4)
> 1, 000,000	23 (15.3)	21 (28.0)	44 (19.6)
Mean WTP Amount (Ugx)	604, 201	791, 358	664,840

Source: Field survey, (2022). Note: Percentages are in parenthesis

4.3.2 Determinants of Household Willingness to pay for domestic biogas systems

To ascertain the determinants of household willingness to pay for domestic biogas systems, the probit model was used. The Chi-square value of 0.9322 showed that the likelihood ratio statistics were highly significant ($p < 0.01$) suggesting that the model had strong explanatory power. The goodness of fit was insignificant which implied model fit. The Variance Inflation Factor (VIF) test had a mean VIF of 1.17. All the independent variables in the probit model for household willingness to pay had VIF values of less than 2 which is highly acceptable and meant that the level of multicollinearity was not severe (Lee, 2013).

Seven variables were found to significantly influence household willingness to pay for domestic biogas systems. These are perception score, distance to firewood source, tropical livestock unit, water availability, access to technicians, location (rural) and gender (female). Marginal effects of the probit model results were estimated and used for interpretation of results given that the coefficients of the equation have no direct interpretation and are only used to maximize the

likelihood function. Positive statistically significant predictors of household willingness to pay for domestic biogas systems are perception score ($p < 0.01$), tropical livestock unit ($p < 0.10$), location (rural) ($p < 0.05$), distance to firewood source ($p < 0.05$), and gender (female) ($p < 0.01$), water availability ($p < 0.01$), and access to technicians ($p < 0.01$). However, household income and participation in biogas project did not influence households' willingness to pay for domestic biogas systems.

Table 7: Probit regression model results with marginal effects

Variable	Coefficients	Marginal effects	p-values
Household Income	0.138(0.094)	0.007(0.004)	0.140
Perception score	29.111(6.686)	1.466(0.185) ***	0.000
Distance to firewood source	-0.104(0.045)	0.005(0.002) **	0.020
Tropical livestock unit	0.831(0.501)	0.042(0.024) *	0.097
Water availability	3.694(1.079)	0.182(0.423) ***	0.001
Participation in biogas project	0.980(0.722)	0.049(0.035)	0.174
Access to technicians	1.927(0.736)	0.097(0.032) ***	0.009
Location (rural)	1.188(0.561)	0.060(0.026) **	0.034
Gender (female)	1.422(0.557)	0.072(0.025) ***	0.011
Constant	-14.660(3.761)		0.000
P-value		0.000	
Log-likelihood		-22.963	
Number of observations		250	
Pseudo R2		0.7175	
GOF – Pearson Chi2 (240) = 75.22; Prob > Chi2 = 0.9322			
Mean VIF	1.17		

Source: Field survey, (2022); Number of respondents =250

4.3.2 Determinants of payment levels for domestic biogas systems

To ascertain the determinants of payment levels for domestic biogas systems, the Tobit model was used. A total of 25 observations having zero values were censored while 225 observations were uncensored. The likelihood ratio value of -3317.33 were highly significant ($P < 0.01$) suggesting that the model had strong explanatory power. Four variables were found to significantly influence the payment levels for domestic biogas systems. These are gender (male),

paraffin use, tropical livestock unit, and participation in biogas project. Tropical livestock unit and participation in biogas project positively influenced the payment levels for domestic biogas systems whereas gender and paraffin use influenced the payment levels for domestic biogas systems negatively.

Table 8: Tobit regression model showing the determinants of payment levels for domestic biogas systems

Variable	**Coefficients**	**Std. Err**	**P > | t |**
Gender (Male)	-278983.6 ***	81903.5	0.001
Paraffin use	-153551.9 *	86376.7	0.077
Income	32700.5	22976.5	0.156
Livestock management	-78515.3	87251.4	0.369
Tropical livestock unit	32621.3 **	15970.7	0.042
Education of household head	10610.0	9000.5	0.240
Age	72418.8	131066.6	0.581
Participation in biogas project	164946.8 *	92218.3	0.075
Lambda	-633583.7	246297.7	0.011
Constant	92741.7	615328	0.880
Log-likelihood	-3317.33		
LR chi2 (9)	70.81		
Prob > chi2	0.0000		
Pseudo R2	0.0106		
Mean VIF	1.13		

Source: Field survey, (2022); Number of respondents =250

CHAPTER FIVE: DISCUSSIONS

5.1 Socio-demographic characteristics of cattle producers

The results (Table 3) showed that the average age of the cattle producers in both districts were agile, youthful, and strong enough to carry out cattle production enterprise of which its management is often capital intensive and laborious. The mean age of the household head reported in this study was higher than the national average age of household heads in Uganda estimated at 38 years (UBOS, 2020). However, it is similar to findings for cattle-producing households in other countries in sub–Saharan Africa such as Kenya (Mutua *et al*., 2017), South Africa (Motiang & Webb, 2016) Malawi (Chirwa & Matita, 2012), and Nigeria (Adesehinwa *et al*., 2004). This result implied that there were few youths engaged in cattle production, which may be attributed to the fact that most young people prefer salaried and skilled occupations to farming (Mutua *et al*., 2017).

In most smallholder farming households, the main source of labor is family labor. In this study, the reported household size of six persons was higher than the national average of five, but lower the national average for rural areas (UBOS (2016b). Household sizes usually vary by location (Okello et al., 2019). In this study for instance, households in Kitgum district had more members than those in Gulu district. By having more members, cattle farming households are also expected to have potentially more supply of family labor. However, whether this labor is available for utilization depends on several factors including age distribution within the household (Anim *et al*., 2011).

The average house hold income reported (Ushs. 540,636) was higher than the national average of Ushs. 412,400 per month for low skilled households (UBOS 2019). This could be because the study focused on cattle producing households that are rarely among the poorest (Wolff *et al*., 2019). An increase in the house hold's income is expected to influence the household's disposable income that may be used to purchase of assets. The mean years of education was eight (8) implying that they have some level of literacy that can enable them to process input and market-related information for better decision making.

Households that participated in the study had about four (4) cattle far less than the national average of 7 (UBOS, 2009). This could be because of the uneven cattle distribution in the country. The National livestock census revealed that the Northern region owns only 14% of cattle, less than other regions such as Eastern (23%), Northeastern (20%), Central (19%), and southwestern (16%) (UBOS, 2009).

The results from Table 4 indicate that about three-quarters of the households were male-headed, 7% higher than the national average of 69% (UBOS, 2020) This could be due to the fact there were more households from rural areas as compared to urban area that participated in the study. UBOS (2016b) affirms that rural households have a higher count of male heads as compared to their urban counterparts. Furthermore, the results concur with a similar study conducted by Bundala *et al*. (2020) in Tanzania and Motiang & Webb (2016) in South Africa which reported that more than 75% of households engaged in cattle production were male-headed. In the context of African settings, men still dominate large ruminant ownership with women focusing on small ruminants such as goats and sheep (Zahra *et al*., 2014).

Most (67.6%) of the respondents were located in a rural area. Rural areas are usually endowed with resources such as grazing fields that support cattle production. The study findings align with with Bettencourt *et al*., (2015) who revealed that the percentage of urban households with livestock is much lower than that of rural households. In most cases, urban households have limited production resources hence mostly engage in poultry and pig production, with only a few engaging in cattle production (Prain & Lee-Smith, 2010).

Many of the respondents were married, implying that they may have ventured into the cattle rearing business to cater for the needs of their families. In both districts, a large percentage of respondents (76%) are unskilled, which may explain their involvement in the cattle rearing business, a venture common among the uneducated.

5.2 Factors influencing household perception of domestic biogas systems

The result (Table 5) showed that an increase in household income increased the chance of a household to have a positive perception towards domestic biogas systems. This could be because an increase in income is associated with improved social status and a preference for more innovative domestic energy sources. It could also be because an increase in income is associated with the more economic capacity to install the domestic biogas systems and afford the associated maintenance costs. These findings are in agreement with Geddafa *et al*., (2021) who reported that annual income positively and significantly influenced decisions to adopt biogas technology among rural households of Aleta, Wondo district in Ethiopia. Furthermore, Ntanos *et al*., (2018) reported that household income was positively associated with public opinion about renewable energy sources in Greece. Nevertheless, the result contradicts with Wawa (2012) who conducted a similar study in Tanzania and found that annual income of the household head influenced

biogas uptake negatively. Implying, household heads earning more income were less likely to adopt the technology. This is because these received lower subsidies as compared to household heads with less income.

Access to technical services was positively and significantly correlated with a positive perception of domestic biogas systems. Those who had access to technical services are 27.9% more likely to perceive perception positively than those who did not have access to technical services. This implied that a household's access to technicians that offer construction and maintenance services fosters reputability and a positive perception of the technology. This finding correlates with those of Geddafa *et al*., (2021) and Nasery (2011) who conducted similar studies in Ethiopia and India respectively and concluded that access to trained technicians by grassroots households promoted the households' ability to adopt biogas technology and to sustainably produce and utilize biogas energy. In addition, Uhunamure (2019) reported that limited access to technical services limited interested households in considering the technology in South Africa.

Gender of the household head was also found to have a significant effect on the household perception of domestic biogas systems. The male household heads were 12.1% less likely to have a positive perception of domestic biogas systems than their female counterpart. The findings of this study resonate with Tarhini *et al*., (2014) who concluded that women and men experience and handle energy-related issues differently owing to their gender roles. They also concur with Behera *et al*., (2016) who reported that male heads of households in Bhutan were less likely to opt for clean energy as compared to their female counterparts. This is because, in a context like Northern Uganda, the male is less engaged in domestic chores like cooking as compared to the female. The associated health risks of using unclean domestic fuels, therefore,

affect women more given that they have high exposure to smoke-filled kitchens (Getachew & Berhanu, 2013; Li *et al*., 2016; Namugenyi *et al*., 2022). However, Bain & Rice (2006) on the contrary, in their study on the influence of gender on attitudes, perceptions, and uses of technology reported that men are more positive about innovations than women, hence more likely to positively perceive technologies.

Marital status had a significant effect on the household perception of domestic biogas systems. The married were 13.3% more likely to have a positive perception of domestic biogas systems than the unmarried. This might be because married farmers have better access to knowledge and resources than unmarried farmers, increasing their chance of participating in new technologies (Nnadi & Akwiwu, 2008). Marriage, according to Donye *et al*., (2012) and Chikezie *et al*., (2012), enhances a farmer's care for the wellbeing of his or her home. As a result, married people are more inclined to positively perceive cleaner fuels such as biogas. For this reason, the married are more likely to have a positive perception of cleaner domestic fuels like biogas. Results concur with Gezahegn *et al*., (2018) who conducted a study on the adoption of renewable energy technologies in rural Tigray, Ethiopia, and reported that the married were more likely to adopt renewable technology as compared to the unmarried.

Further, findings revealed that households located in the rural area were 16.0% less likely to have a positive perception of domestic biogas systems than those in the urban area. This is in agreement with findings of Walekhwa *et al*., (2009) in a comparable research, who found that the chance of a family adopting biogas technology in Uganda reduced as the remoteness of the household increased. This might be due to a lack of awareness owing to a lack of access to communication networks such as the mass media.

In the same vein, households who practiced the free-range livestock management system were 25% less likely to have a positive perception of domestic biogas systems than those who practiced other livestock management systems. This is in agreement with Fentie & Sime (2022) and Mwirigi *et al*., (2009) who observed that households in Northern Ethiopia and Kenya respectively, that practiced free-range livestock management had a lower potential to take up biogas technology as compared to those that were using controlled grazing. Management systems in Northern Ethiopia and Kenya, respectively. This is because of the hurdles associated with collecting animal dung in an extensive livestock management system like free range (Bößner *et al*., 2019; Aikhuele *et al*., 2020).

Also, households that had access to enough waste were 13.7% more likely to have a positive perception of domestic biogas systems than those that did not have access to enough waste. This is because access to waste is one of the most important factors for the successful operation of a domestic biogas system (GHU *et al*., 2013).

5.3 Determinants of Household Willingness to pay and payment levels for domestic biogas systems

5.3.1 Determinants of Household Willingness to pay for domestic biogas systems

The result (Table 7) showed that an increase in perception score increased the probability of a household WTP for domestic biogas systems. People who perceive a technology positively are more likely to pay for it. This is in tandem with Ngcobo *et al*. (2022) who in their study on adoption and perceptions of biogas among rural households of Melani village in Raymond Mhlaba municipality South Africa concluded that perceptions played a significant role in households' adoption and decision to invest in biogas technology.

It was further revealed that the more the distance to firewood source, the more the probability of the household WTP for domestic biogas systems. This could be because biogas reduces the burden of collecting fuel (Mukisa *et al*., 2022). Findings are similar to Mengistu *et al*. (2016) who studied biogas adoption in Ethiopia and found that distance to main fuel wood source positively influenced household's decision to invest in domestic biogas. According to Ferrer *et al*., (2011) and Kasap *et al*., (2012) use of biogas reduced workload for women and girls by 50% allowing them time to participate in other productive activities.

A positive and significant relationship was observed between the probability of WTP for domestic biogas systems and tropical livestock unit. Livestock is the major source of feedstock in domestic biogas production, hence households with more livestock are more likely to invest in the technology due to availability of feedstock to feed the digesters as compared to their counterparts with few livestock (Walekhwa *et al*., 2009). Results are consistent with the findings of Kabyanga *et al*., (2018a) who conducted a related study in central Uganda and found that that a 1% increase livestock numbers results into an increase of the probability of paying for the digester by 11.9%.

In addition, water availability exhibited a positive and significant influence on household WTP for domestic biogas systems. This is because operating a biogas plant requires a substantial amount of water to be mixed with the feedstock hence limited availability of water poses a constraint to biogas operation (Malla *et al*., 2011). The additional time and labor required to mix water and manure daily further limits households' willingness to pay and adopt the technology. Mwakaje (2008) in his study on Dairy farming and biogas use in Rungwe district South-west

Tanzania reported that despite having a demand of over 90% and other favorable conditions, biogas uptake was constrained by water availability.

It was observed that households who had access to technicians had more probability of WTP for domestic biogas systems than those who had no access to technicians. This could be because limited access to biogas technicians' results translates to scarcity of technical knowledge and inappropriate management hence failure of biogas programs, and subsequently causing a negative image of the technology. Cognizant that trust is paramount in persuading clients to invest in new technologies Nevzorova & Kutcherov (2019), access to technicians positively influences WTP for the technology. Study findings are consistent with a similar study that was conducted in South Africa which found that inadequate expertise for construction and maintenance of the biogas digesters affected house hold's decision to pay for the technology (Mukumba *et al*., 2016). Whereas, in Eastern Uganda, Mukisa *et al*., (2022) reported that limited access to technical expertise was a main bottleneck to biogas uptake. Similarly, Mugo & Gathea (2010) underscored the need to have sufficient number of local artisans at the community level to offer construction and maintenance services to interested clients.

Furthermore, households who resides in rural areas were 6% more likely to pay for domestic biogas systems than those who resides in urban areas. This could be because households in the rural areas have limited access to alternative clean domestic energy sources like LPG, Electricity as compared to their counter parts in urban settings. Results contradict with findings from Walekhwa *et al*. (2009) in a related study who concluded that the likelihood of a household to adopt biogas technology in Central Uganda decreased with increasing remoteness of the

household location. The contradiction in the findings could be attributed to the contextual differences between the regions.

More so, it was observed that females were 7.2% more likely to pay for domestic biogas systems than their male counterparts. This may be because women are traditionally more responsible for domestic fuel use, sanitation and hygiene hence are more receptive to technologies that offer innovative solutions to challenges in the above-mentioned areas. Kabir *et al*., (2013) in a similar study in Bangladesh found that women headed family have significant influences on the decision of biogas plant installation. Similarly, In Ethiopia, A significantly higher proportion of the female farmers were willing to pay for eco-friendly Agricultural Waste Management as compared to their male counterparts (Atinkut *et al*., 2020). However, On the contrary, Vaidy (2019) conducted a similar study and results showed that women had minimal engagement in making decisions relating to the purchase of the biogas, and in Eastern Malaysia, Gender did not affect Household's decision to pay for biogas systems (Aini & Ling, 2013).

5.3.2 Determinants of payment levels for domestic biogas systems

The result (Table 8) showed that those who had participated in biogas project were willing to pay more for domestic biogas systems than those who have not participated in biogas project. This could be because participation in a biogas project increases households' knowledge of the technology (Amigun *et al*., 2012). Results coincide with Padi *et al*., (2015) who concluded that knowledge about the technology positively influenced willingness to pay amount for improved solid waste management in Ghana. Similarly, Hojnik *et al*., (2021) reported that knowledge was linked to high willingness to pay for green energy in Slovenia. Sardianou & Genoudi (2013) asserted that sufficient knowledge regarding the technology can positively influence the uptake

of the technology. This in turn increases the amount of money that households are willing to invest in the technology.

Furthermore, it was discovered that the male headed households were willing to pay less for domestic biogas systems than their female counterparts. Results are congruent with the findings of GHU *et al*., (2013) who found that male headed households were willing to pay UGX 164,000 less than the female headed households for domestic biogas systems in central Uganda. However, (Adeleke *et al*., 2022) conducted a similar study and concluded that Gender did not influence payment levels for Renewable Energy Technologies (RET) in Nigeria. The disparity in findings might be attributed to differences in context across the research areas.

The use of paraffin for lighting significantly exerted negative influence on payment levels for domestic biogas systems. This meant that the use of paraffin reduced the amount of money that households were willing to pay for domestic biogas systems. This could be due to the fact that mostly poorer households rely on paraffin for lighting and these do not have financial resources to invest in domestic biogas systems. Findings are in contrast with Bhandari & Jana (2010) who conducted a similar study and revealed that paraffin use by households positively influenced the amount they were willingness to invest in renewable energy.

Tropical livestock unit (TLU) significantly exerted positive influence on payment levels for domestic biogas. This implied that the more the number of livestock owned by households, the higher the amount they are willing to pay for domestic biogas. According to Guta (2020), the more livestock a household owned expressed as Tropical livestock unit, the wealthier it was hence the higher the financial capacity to pay for biogas. Atinkut *et al*., (2020) further asserted

that households with a higher TLU were more cautious of the adverse effects of manure and droppings hence willing to pay more for renewable energy.

CHAPTER SIX:

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study sought to ascertain the perception and willingness to pay for domestic biogas systems in Gulu and Kitgum districts, northern Uganda. Specifically, the study aimed at characterizing cattle producing households by their socio-economic status, establishing the factors influencing households' perception of domestic biogas systems and ascertaining households' willingness to pay for domestic biogas systems. A cross sectional study was conducted in Gulu and Kitgum districts wherein 250 cattle producing households were interviewed using pretested structured questionnaires. Data were analyzed using descriptive statistics, binary logistic model and double hurdle model.

In terms of households' perception of domestic biogas systems, the probability of positive perception of this biogas systems increased with increasing household income, household member being married, access to technician and access to enough waste and decreased with male gender, rural location of household, and free-range livestock management systems.

With regards to WTP for domestic biogas system, the probability of WTP increased with increasing perception score, tropical livestock unit and distance to firewood source. Location gender, water availability, and access to technicians were also found to exert positive significant effect on household willingness to pay for domestic biogas systems.

Payment levels for domestic biogas system increased with increasing tropical livestock unit and participation in biogas project. Nonetheless, it decreased with increasing paraffin use and by male gender.

6.2 Recommendations

6.2.1 Policy recommendations

In order to improve the utilization of domestic biogas system, the following can be considered by policy makers, NGOs and other stakeholders for implementation.

1. Smallholder farming household especially those who own livestock should be incentivized to shift from traditional biomass and harness the potential in domestic biogas systems as their source of cooking energy through participating in demand activation activities such as trainings and demonstration, which are key drivers to perceptions and household decision making on domestic energy
2. Majority of the households (90%) expressed WTP for domestic biogas systems. This therefore presents a business potential for young people who were relatively more positive about biogas. Funding for domestic biogas producing businesses is highly recommended, as this will ultimately lead to the creation of job opportunities.
3. Programs that would ensure sufficient awareness and positive perception of domestic biogas systems should be developed by the government. Prices of domestic biogas systems should be regulated and made affordable for both rural and urban dwellers.
4. Stakeholders engaged in the promotion of domestic biogas systems i.e NGOs, Private sector, Government and Universities should invest in creating a system that ensures that cattle keeping households have sustainable access to technical services for the installation

and maintenance of domestic biogas systems. This may involve training and building capacity of technical service providers to carry out technical service provision as a business.

5. Programs that are promoting biogas uptake should focus on both female and male headed households. For female-headed households that mostly reported a positive perception towards the technology and were also willing to pay more for domestic biogas systems, focus should be on making the systems and technical services more affordable, whereas for the male-headed households, there is need to popularize the technology.

6.3.2 Recommendations for further studies

The study focused on WTP for domestic biogas system among cattle producing households. It will however be relevant to assess the WTP for domestic biogas among other livestock producing households for comparison. Similarly, the study suggests that another study be conducted on domestic biogas system in other areas for comparison since the study could not cover the entire country.

REFERENCES

Abdullah, S., & Mariel Chladkova, P. (2009). Choice experiment study on the willingness to pay to improve electicity services. *Energy policy, Elsevier, vol. 38(8), pgs 4570-4581*

Abigail Padi, John Awuah Addor, & Victor Nunfam. (2015). An Econometric Model of Factors Influencing Households' Willingness to Pay for Improved Solid Waste Management Service within the Sekondi-Takoradi Metropolis in the Western Region of Ghana. *Journal of Economics and Sustainable Development*, *6*(16), 15–30.

Adeleke, A. T., Odesola, O. V., Hussayn, J. A., Odesola, M. M., & Odesola, O. (2022). Household poverty status and willingness to pay for renewable energy technologies: Evidence from Southwestern Nigeria. *Environmental Sciences Proceedings*, *15*(1), 3.

Adesehinwa, A. O. K., Okunola, J. O., & Adewumi, M. K. (2004). Socio-economic characteristics of ruminant livestock farmers and their production constraints in some parts of South-western Nigeria. *Livestock Research for Rural Development*, *16*(8), 2004.

Aggarangsi, P., Tippayawong, N., Moran, J. C., & Rerkkriangkrai, P. (2013). Overview of livestock biogas technology development and implementation in Thailand. *Energy for Sustainable Development*, *17*(4), 371–377.

Aikhuele, J., Eniola, V., Aikhuele, A., & Awuapila, O. F. N. (2020). The Implementation of Biogas Production from Municipal Solid Waste in Nigeria. *J Energy Technol Policy*, *10*(1), 61–68.

Aini, M. S., & Goh Mang Ling, M. (2013). Factors Affecting the Willingness to Pay for Renewable Energy amongst Eastern Malaysian Households: A Case Study. *Pertanika Journal of Social Sciences \& Humanities*, *21*(1).

Amigun, B., Parawira, W., Musango, J. K., Aboyade, A. O., & Badmos, A. S. (2012). Anaerobic

biogas generation for rural area energy provision in Africa. *Biogas*, 36–62.

Arega, T., & Tadesse, T. (2017). Household willingness to pay for green electricity in urban and peri-urban Tigray, northern Ethiopia: Determinants and welfare effects. *Energy Policy, 100*, 292–300.

Atinkut, H. B., Yan, T., Arega, Y., & Raza, M. H. (2020). Farmers' willingness-to-pay for eco-friendly agricultural waste management in Ethiopia: A contingent valuation. *Journal of Cleaner Production, 261*, 121211.

Audu, V. I., & Aye, G. C. (2014). The effects of improved maize technology on household welfare in Buruku, Benue State, Nigeria. *Cogent Economics and Finance*, *2*(1). https://doi.org/10.1080/23322039.2014.960592

Baena-Moreno, F. M., Rodríguez-Galán, M., Vega, F., Alonso-Fariñas, B., Vilches Arenas, L. F., & Navarrete, B. (2019). Carbon capture and utilization technologies: a literature review and recent advances. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *41*(12), 1403–1433. https://doi.org/10.1080/15567036.2018.1548518

Bain, C. D., & Rice, M. L. (2006). The influence of gender on attitudes, perceptions, and uses of technology. *Journal of Research on Technology in Education*, *39*(2), 119–132. https://doi.org/10.1080/15391523.2006.10782476

Balana, B. B., Catacutan, D., & Mäkelä, M. (2013). Assessing the willingness to pay for reliable domestic water supply via catchment management: results from a contingent valuation survey in Nairobi City, Kenya. *Journal of Environmental Planning and Management*, *56*(10), 1511–1531.

Bamwesigye, D., Kupec, P., Chekuimo, G., Pavlis, J., Asamoah, O., Darkwah, S. A., & Hlaváčková, P. (2020). Charcoal and wood biomass utilization in Uganda: the

socioeconomic and environmental dynamics and implications. *Sustainability*, *12*(20), 8337.

Behera, B., Ali, A., & others. (2016). Patterns and determinants of household use of fuels for cooking: Empirical evidence from sub-Saharan Africa. *Energy*, *117*, 93–104.

Bettencourt, E. M. V., Tilman, M., Narciso, V., Carvalho, M. L. da S., & Henriques, P. D. de S. (2015). The livestock roles in the wellbeing of rural communities of Timor-Leste. *Revista de Economia e Sociologia Rural*, *53*, 63–80.

Bhandari, A. K., & Jana, C. (2010). A comparative evaluation of household preferences for solar photovoltaic standalone and mini-grid system: An empirical study in a costal village of Indian Sundarban. *Renewable Energy*, *35*(12), 2835–2838.

Bishop, R. C., & Heberlein, T. A. (1979). Measuring values of extramarket goods: Are indirect measures biased? *American Journal of Agricultural Economics*, *61*(5), 926–930.

Blondeel, M., Bradshaw, M. J., Bridge, G., & Kuzemko, C. (2021). The geopolitics of energy system transformation: A review. *Geography Compass*, *15*(7), e12580.

Bößner, S., Devisscher, T., Suljada, T., Ismail, C. J., Sari, A., & Mondamina, N. W. (2019). Barriers and opportunities to bioenergy transitions: An integrated, multi-level perspective analysis of biogas uptake in Bali. *Biomass and Bioenergy*, *122*, 457–465.

Boxall, P. C., Cash, S. B., Wismer, W. V, Muralidharan, V., & Annett, L. E. (2007). *The role of sensory experiences and information on the willingness to pay for organic wheat bread*.

Bundala, N., Kinabo, J., Jumbe, T., Rybak, C., & Sieber, S. (2020). Does homestead livestock production and ownership contribute to consumption of animal source foods? A pre-intervention assessment of rural farming communities in Tanzania. *Scientific African*, *7*, e00252.

Çeliköz, N., Eri\csen, Y., & \cSahin, M. (2019). Cognitive learning theories with emphasis on

latent learning, gestalt and information processing theories. *Journal of Educational and Instructional Studies in the World*, *9*(3).

Chen, L., Zhao, L., Ren, C., & Wang, F. (2012). The progress and prospects of rural biogas production in China. *Energy Policy*, *51*, 58–63.

Chikezie, N. P., Omokore, D. F., Akpoko, J. G., & Chikaire, J. (2012). Factors Influencing rural youth adoption of cassava recommended production practices in Onu-Imo local government area of Imo State, Nigeria. *Greener Journal of Agricultural Sciences*, *2*(6), 259–268.

Chirwa, E. W., & Matita, M. (2012). *From subsistence to smallholder commercial farming in Malawi: A case of NASFAM commercialisation initiatives*.

Clemens, H., Bailis, R., Nyambane, A., & Ndung'u, V. (2018). Africa Biogas Partnership Program: A review of clean cooking implementation through market development in East Africa. *Energy for Sustainable Development*, *46*, 23–31. https://doi.org/10.1016/j.esd.2018.05.012

Cragg, J. G. (1971). *This content downloaded from 77.103.16.28 on Wed*. *39*(5), 829–844.

Dinegde, N. G., & Xuying, L. (2017). Awareness of breast cancer among female care givers in tertiary cancer hospital, China. *Asian Pacific Journal of Cancer Prevention*, *18*(7), 1977–1983. https://doi.org/10.22034/APJCP.2017.18.7.1977

Donye, A. O., Gwary, M. M., Nuhu, H. S., Zhintswen, A. A., & others. (2012). Assessment of youth involvement in yam production in Wukari local Government area of Taraba State, Nigeria. *Agriculture and Biology Journal of North America*, *3*(8), 311–317.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carr, G., & Lautenbach, S. (2013). *Collinearity: a review of methods to deal with it and a simulation study evaluating their performance.(February 2012), 27--46*.

Du Can, S. de la R., Pudleiner, D., & Pielli, K. (2018). Energy efficiency as a means to expand energy access: A Uganda roadmap. *Energy Policy, 120*, 354–364.

Ebhota, W. S. (2019). Power accessibility, fossil fuel and the exploitation of small hydropower technology in sub-saharan Africa. *International Journal of Sustainable Energy Planning and Management*, *19*, 13–28.

Ekesa, B., Fongar, A., & Nasser, M. (2022). Access to and Utilization of Wild Species for Food and Nutrition Security in Teso and Acholi Sub-regions of Uganda. *Frontiers in Sustainable Food Systems*, 247.

Engel, C., & Moffatt, P. G. (2014). Dhreg, xtdhreg, and bootdhreg: Commands to implement double-hurdle regression. *Stata Journal*, *14*(4), 778–797. https://doi.org/10.1177/1536867x1401400405

Fentie, H., & Sime, G. (2022). Biogas technology adoption and its potential of replacing biomass fuels, kerosene, and chemical fertilizer in rural Gonder, Northern Ethiopia. *Sustainable Environment*, *8*(1), 1–14.

Ferrer, I., Garfí, M., Uggetti, E., Ferrer-Martí, L., Calderon, A., & Velo, E. (2011). Biogas production in low-cost household digesters at the Peruvian Andes. *Biomass and Bioenergy*, *35*(5), 1668–1674. https://doi.org/10.1016/j.biombioe.2010.12.036

Florio, C., Fiorentino, G., Corcelli, F., Ulgiati, S., Dumontet, S., Güsewell, J., & Eltrop, L. (2019). A life cycle assessment of biomethane production from waste feedstock through different upgrading technologies. *Energies*, *12*(4), 1–12. https://doi.org/10.3390/en12040718

Geddafa, T., Melka, Y., & Sime, G. (2021). Determinants of Biogas Technology Adoption in Rural Households of Aleta Wondo District, Sidama Zone, Southern Ethiopia. *Journal of*

Energy, *2021*.

Getachew, D. G., & Berhanu, A. D. (2013). Quantification of the potential for biogas and biogas manure from the selected fruit wastes in Addis Ababa city, Ethiopia. *African Journal of Environmental Science and Technology*, *7*(12), 1037–1043.

Gezahegn, T. W., Gebregiorgis, G., Gebrehiwet, T., & Tesfamariam, K. (2018). Adoption of renewable energy technologies in rural Tigray, Ethiopia: An analysis of the impact of cooperatives. *Energy Policy*, *114*(February 2017), 108–113. https://doi.org/10.1016/j.enpol.2017.11.056

GHU, G. D., Glenk, K., MU, J. B. T., Tumwesige, V., & others. (n.d.). *The Potential of Small-Scale Biogas Digesters to Improve Livelihoods and Long Term Sustainability of Ecosystem Services in Sub-Saharan Africa*.

Gielen, D., Gorini, R., Leme, R., Prakash, G., Wagner, N., Janeiro, L., Collins, S., Kadir, M., Asmelash, E., Ferroukhi, R., & others. (2021). *World energy transitions outlook: 1.5° C pathway*.

Gustavsson, M., & Broad, O. (2015). *Energy Report for Uganda*.

Guta, D. D. (2014). Effect of fuelwood scarcity and socio-economic factors on household bio-based energy use and energy substitution in rural Ethiopia. *Energy Policy*, *75*, 217–227. https://doi.org/10.1016/j.enpol.2014.09.017

Guta, D. D. (2020). Determinants of household use of energy-efficient and renewable energy technologies in rural Ethiopia. *Technology in Society*, *61*, 101249. https://doi.org/10.1016/j.techsoc.2020.101249

Hanemann, W. M., & Kanninen, B. (1996). *The statistical analysis of discrete-response CV data*.

Hashim, H., & Ho, W. S. (2011). Renewable energy policies and initiatives for a sustainable

energy future in Malaysia. *Renewable and Sustainable Energy Reviews*, *15*(9), 4780–4787.

Hernández-Castellano, L. E., Nally, J. E., Lindahl, J., Wanapat, M., Alhidary, I. A., Fangueiro, D., Grace, D., Ratto, M., Bambou, J. C., & de Almeida, A. M. (2019). Dairy science and health in the tropics: challenges and opportunities for the next decades. *Tropical Animal Health and Production*, *51*(5), 1009–1017.

Hoehn, J. P., & Randall, A. (1987). A satisfactory benefit cost indicator from contingent valuation. *Journal of Environmental Economics and Management*, *14*(3), 226–247.

Hojnik, J., Ruzzier, M., Fabri, S., & Klopčič, A. L. (2021). What you give is what you get: Willingness to pay for green energy. *Renewable Energy*, *174*, 733–746.

Ikram, M., Sroufe, R., Rehman, E., Shah, S. Z. A., & Mahmoudi, A. (2020). Do Quality, Environmental, and Social (QES) Certifications Improve International Trade? A Comparative Grey Relation Analysis of Developing vs. Developed Countries. *Physica A: Statistical Mechanics and Its Applications*, *545*. https://doi.org/10.1016/j.physa.2019.123486

Jules, F., & Navalona, T. (2022). *Biomass and Bioenergy Integration of biogas technology into livestock farming : Study on farmers ' willingness to pay for biodigesters in Madagascar*. *164*(July).

Adeyemi, K. O., & A.A. Asere. (2014). A review of the energy situation in uganda. *International Journal of Scientific and Research Publications*, *4*(1), 2–5.

Kabasingwa, E. (2019). *Assessing the Diffusion of Renewable Energy Technologies and Socio-economic Development: A Ripple Effect Analysis of Two Policy Choices: Inclusive Clean-burning, Fuel-efficient Cook-stoves and Solar PVs for Street Lighting, Institutional and Home Applicat*. PAUWES.

Kabir, H., Palash, M. S., & Bauer, S. (2012). Appraisal of domestic biogas plants in Bangladesh. *Bangladesh Journal of Agricultural Economics*, *35*(454-2016–36351), 71–89.

Kabir, H., Yegbemey, R. N., & Bauer, S. (2013). Factors determinant of biogas adoption in Bangladesh. *Renewable and Sustainable Energy Reviews*, *28*, 881–889. https://doi.org/10.1016/j.rser.2013.08.046

Kabyanga, M., Balana, B. B., Mugisha, J., Walekhwa, P. N., Smith, J., & Glenk, K. (2018a). Are smallholder farmers willing to pay for a flexible balloon biogas digester? Evidence from a case study in Uganda. *Energy for Sustainable Development*, *43*, 123–129.

Kabyanga, M., Balana, B. B., Mugisha, J., Walekhwa, P. N., Smith, J., & Glenk, K. (2018b). Economic potential of flexible balloon biogas digester among smallholder farmers: A case study from Uganda. *Renewable Energy*, *120*, 392–400.

Kandpal, T. C., Joshi, B., & Sinha, C. S. (1991). Economics of family sized biogas plants in India. *Energy Conversion and Management*, *32*(2), 101–113.

Kaplan, D., & Venezky, R. L. (1994). Literacy and voting behavior: A bivariate probit model with sample selection. *Social Science Research*, *23*(4), 350–367.

Kasap, A., Aktas, R., & Dulger, E. (2012). Economic and environmental impacts of Biogas. *Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)*, *8*(3), 271–277.

Kaygusuz, K. (2012). Energy for sustainable development: A case of developing countries. *Renewable and Sustainable Energy Reviews*, *16*(2), 1116–1126.

Kebede, E., Kagochi, J., & Jolly, C. M. (2010). Energy consumption and economic development in Sub-Sahara Africa. *Energy Economics*, *32*(3), 532–537.

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of Adoption and Impacts of

Improved Maize Varieties in Eastern Zambia. *World Development*, *66*, 695 706-706. https://doi.org/10.1016/j.worlddev.2014.09.008

Kong, F., Xiong, K., & Zhang, N. (2014). Determinants of farmers' willingness to pay and its level for ecological compensation of Poyang lake wetland, China: A household-level survey. *Sustainability (Switzerland)*, *6*(10), 6714–6728. https://doi.org/10.3390/su6106714

Lambrinou, E., Sourtzi, P., Kalokerinou, A., & Lemonidou, C. (2009). Attitudes and knowledge of the Greek nursing students towards older people. *Nurse Education Today*, *29*(6), 617–622.

Lee, L. Y.-T. (2013). Household energy mix in Uganda. *Energy Economics*, *39*, 252–261.

Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-Based Dentistry*, *7*(1), 24–25.

Li, F., Cheng, S., Yu, H., & Yang, D. (2016). Waste from livestock and poultry breeding and its potential assessment of biogas energy in rural China. *Journal of Cleaner Production*, *126*, 451–460.

Lietaer, S., Zaccai, E., & Verbist, B. (2019). Making cooking champions: Perceptions of local actors on private sector development in Uganda. *Environmental Development*, *32*, 100452.

Lim, C. I., & Biswas, W. K. (2019). Sustainability implications of the incorporation of a biogas trapping system into a conventional crude palm oil supply chain. *Sustainability (Switzerland)*, *11*(3). https://doi.org/10.3390/su11030792

Limmeechokchai, B., & Chawana, S. (2007). Sustainable energy development strategies in the rural Thailand: The case of the improved cooking stove and the small biogas digester. *Renewable and Sustainable Energy Reviews*, *11*(5), 818–837. https://doi.org/10.1016/j.rser.2005.06.002

Lin, T.-F., & Schmidy, P. (1984). A Test of the Tobit Specification Against an Alternative Suggested by Cragg. *STOR, 66*(1), 174–177.

Luo, X., & Xu, X. (2018). Infrastructure, value chains, and economic upgrades. *World Bank Policy Research Working Paper, 8547*.

Lusk, J. L., & Hudson, D. (2004). Willingness-to-pay estimates and their relevance to agribusiness decision making. *Applied Economic Perspectives and Policy*, *26*(2), 152–169.

Lutaaya, F. (2013). *Quality and usage of biogas digesters in Uganda*. Royal institute of Technology Stockholm, Sweden.

Magunda, M. (2020). *Situational analysis study of the agriculture sector in Uganda*.

Mainimo, E. N., Okello, D. M., Mambo, W., & Mugonola, B. (2022). Drivers of household demand for cooking energy: A case of Central Uganda. *Heliyon*, *8*(3), e09118. https://doi.org/10.1016/j.heliyon.2022.e09118

Malla, M. B., Bruce, N., Bates, E., & Rehfuess, E. (2011). Applying global cost-benefit analysis methods to indoor air pollution mitigation interventions in Nepal, Kenya and Sudan: Insights and challenges. *Energy Policy*, *39*(12), 7518–7529. https://doi.org/10.1016/j.enpol.2011.06.031

Malla, S., & Timilsina, G. R. (2014). Household cooking fuel choice and adoption of improved cookstoves in developing countries: a review. *World Bank Policy Research Working Paper, 6903*.

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2018). Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. *Land*, *7*(2), 1–19. https://doi.org/10.3390/land7020049

Mengistu, M. G., Simane, B., Eshete, G., & Workneh, T. S. (2015). A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia. *Renewable and Sustainable Energy Reviews*, *48*(April), 306–316. https://doi.org/10.1016/j.rser.2015.04.026

Mengistu, M. G., Simane, B., Eshete, G., & Workneh, T. S. (2016). Factors affecting households' decisions in biogas technology adoption, the case of Ofla and Mecha Districts, northern Ethiopia. *Renewable Energy*, *93*, 215–227. https://doi.org/10.1016/j.renene.2016.02.066

Motiang, D. M., & Webb, E. C. (2016). Herd mortality and cattle off-take rates among small-holder producers in the North West Province of South Africa. *African Journal of Agricultural Research*, *11*(11), 930–934.

Mugo, F., & Gathea, T. (2010). A background paper prepared for the International Institute for Environment and Development (IIED) for an international ESPA workshop on biomass energy, 19-21 October 2010, Parliament House Hotel, Edinburgh. Practical Action, Nairobi, Kenya. *Biomass Energy Use in Kenya*.

Mukisa, N., Manitisa, M. S., Nduhuura, P., Tugume, E., & Chalwe, C. K. (2022). Solar home systems adoption in Sub-Saharan African countries: Household economic and environmental benefits assessment. *Renewable Energy*, *189*, 836–852.

Mukumba, P., Makaka, G., & Mamphweli, S. (2016). Biogas technology in South Africa, problems, challenges and solutions. *International Journal of Sustainable Energy and Environmental Research*, *5*(4), 58–69.

Mukwaya, P. I. (2016). Urban Adaptation to Energy Insecurity in Uganda. *Current Urban Studies*, *04*(01), 69–84. https://doi.org/10.4236/cus.2016.41006

Mutua, E., Bukachi, S., Bett, B., Estambale, B., & Nyamongo, I. (2017). *Youth participation in*

smallholder livestock production and marketing.

Mutungwazi, A., Mukumba, P., & Makaka, G. (2018). Biogas digester types installed in South Africa: A review. *Renewable and Sustainable Energy Reviews*, *81*, 172–180.

Mwakaje, A. G. (2008). Dairy farming and biogas use in Rungwe district, South-west Tanzania: A study of opportunities and constraints. *Renewable and Sustainable Energy Reviews*, *12*(8), 2240–2252.

Mwema, C., & Crewett, W. (2019). Social Networks and Commercialisation of African Indigenous Vegetables in Kenya: A Cragg's Double Hurdle Approach. *Cogent Economics and Finance*, *7*(1). https://doi.org/10.1080/23322039.2019.1642173

Mwirigi, J., Balana, B. B., Mugisha, J., Walekhwa, P., Melamu, R., Nakami, S., & Makenzi, P. (2014). Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan Africa: A review. *Biomass and Bioenergy*, *70*, 17–25. https://doi.org/10.1016/j.biombioe.2014.02.018

Mwirigi, J. W., Makenzi, P. M., & Ochola, W. O. (2009). Socio-economic constraints to adoption and sustainability of biogas technology by farmers in Nakuru Districts, Kenya. *Energy for Sustainable Development*, *13*(2), 106–115. https://doi.org/10.1016/j.esd.2009.05.002

Namugenyi, I., Coenen, L., & Scholderer, J. (2022). Realising the transition to bioenergy: Integrating entrepreneurial business models into the biogas socio-technical system in Uganda. *Journal of Cleaner Production*, *333*, 130135.

Nasery, V. (2011). Biogas for rural communities: center for technology alternatives for rural areas. *Indian Institute of Technology Bombay*.

Nathaniel, S., Anyanwu, O., & Shah, M. (2020). Renewable energy, urbanization, and ecological

footprint in the Middle East and North Africa region. *Environmental Science and Pollution Research*, *27*(13), 14601–14613.

Nevzorova, T., & Kutcherov, V. (2019). Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Reviews*, *26*, 100414.

Ngango, J., & Hong, S. (2021). Speed of adoption of intensive agricultural practices in Rwanda: A duration analysis. *Agrekon*, *60*(1), 43–56. https://doi.org/10.1080/03031853.2021.1883448

Ngcobo, L., Obi, A., Mamphweli, S., & Zantsi, S. (2022). Adoption and perceptions of biogas: Empirical evidence from rural households of Melani village in Raymond Mhlaba municipality. *African Journal of Science, Technology, Innovation and Development*, *14*(2), 350–358. https://doi.org/10.1080/20421338.2020.1819684

Nkunzimana, L., Huart, M., & Zaccai, E. (2014). Toward policies for climate change mitigation:"Barriers for family-sized biogas in the District of Gihanga, Burundi." *Earth's Future*, *2*(5), 245–255.

Nnadi, F. N., & Akwiwu, C. D. (2008). Determinants of youth participation in rural agriculture in Imo State, Nigeria. *Journal of Applied Sciences*, *8*(2), 328–333.

Nosratabadi, S., Mosavi, A., Shamshirband, S., Zavadskas, E. K., Rakotonirainy, A., & Chau, K. W. (2019). Sustainable business models: A review. *Sustainability (Switzerland)*, *11*(6), 1–30. https://doi.org/10.3390/su11061663

Ntanos, S., Kyriakopoulos, G., Chalikias, M., Arabatzis, G., & Skordoulis, M. (2018). Public perceptions and willingness to pay for renewable energy: A case study from Greece. *Sustainability*, *10*(3), 687.

Nyiwul, L. (2017). Economic performance, environmental concerns, and renewable energy

consumption: drivers of renewable energy development in Sub-Sahara Africa. *Clean Technologies and Environmental Policy*, *19*(2), 437–450.

Obubu, J. P., Odong, R., Alamerew, T., Fetahi, T., & Mengistou, S. (2022). Application of DPSIR model to identify the drivers and impacts of land use and land cover changes and climate change on land, water, and livelihoods in the L. Kyoga basin: implications for sustainable management. *Environmental Systems Research*, *11*(1), 1–21.

Ocwieja, S. M. (2010). *Life Cycle Thinking Assessment Applied to Three Biogas Projects in Central Uganda By*.

Okello, C., Pindozzi, S., Faugno, S., & Boccia, L. (2013). Bioenergy potential of agricultural and forest residues in Uganda. *Biomass and Bioenergy*, *56*, 515–525.

Okello, D. M., Bonabana-Wabbi, J., & Mugonola, B. (2019). Farm level allocative efficiency of rice production in Gulu and Amuru districts, Northern Uganda. *Agricultural and Food Economics*, *7*(1), 1–19. https://doi.org/10.1186/s40100-019-0140-x

Osiolo, H. H. (2017). Willingness to pay for improved energy: Evidence from Kenya. *Renewable Energy*, *112*, 104–112. https://doi.org/10.1016/j.renene.2017.05.004

Owusu, P. A., & Banadda, N. (2017). *Livestock waste-to-bioenergy generation potential in Uganda: A review*.

Owusu, V., & Owusu Anifori, M. (2013). Consumer willingness to pay a premium for organic fruit and vegetable in Ghana. *International Food and Agribusiness Management Review*, *16*(1030-2016–82931), 67–86.

Oyeleke, O. J., & Akinlo, T. (2020). Energy generation and economic growth: empirical evidence from Nigeria. *Environment, Development and Sustainability*, *22*(8), 7177–7191. https://doi.org/10.1007/s10668-019-00476-4

Pandey, B., & Bajgain, S. (2007). Feasibility Study of Domestic Biogas in Pakistan. *Rspn*, *July*, 1–38.

Peipert, J., Severyn, T., Hovmand, P. S., & Yadama, G. N. (2008). Modeling the dynamics of the energy, environment, \& poverty nexus: A study of biogas unit diffusion in Andhra Pradesh, India. *Washington University in St. Louis, USA: 13p*.

Prain, G., & Lee-Smith, D. (2010). Urban agriculture in Africa: what has been learned? In *African urban harvest* (pp. 13–35). Springer.

Raha, D., Mahanta, P., & Clarke, M. L. (2014). The implementation of decentralised biogas plants in Assam, NE India: The impact and effectiveness of the National Biogas and Manure Management Programme. *Energy Policy*, *68*, 80–91.

Rao, S., Chirkov, V., Dentener, F., van Dingenen, R., Pachauri, S., Purohit, P., Amann, M., Heyes, C., Kinney, P., Kolp, P., Klimont, Z., Riahi, K., & Schoepp, W. (2012). Environmental Modeling and Methods for Estimation of the Global Health Impacts of Air Pollution. *Environmental Modeling and Assessment*, *17*(6), 613–622. https://doi.org/10.1007/s10666-012-9317-3

Riti, J. S., & Shu, Y. (2016). Renewable energy, energy efficiency, and eco-friendly environment (R-E5) in Nigeria. *Energy, Sustainability and Society*, *6*(1), 1–16.

Ruiz-Mercado, I., Masera, O., Zamora, H., & Smith, K. R. (2011). Adoption and sustained use of improved cookstoves. *Energy Policy*, *39*(12), 7557–7566.

Sardianou, E., & Genoudi, P. (2013). Which factors affect the willingness of consumers to adopt renewable energies? *Renewable Energy*, *57*, 1–4.

Sari, A. I., Suwarto, Suminah, & Purnomo, S. H. (2022). Public acceptance of livestock biogas technology as an environmentally friendly alternative energy. *IOP Conference Series: Earth*

and Environmental Science, *1001*(1), 1–6. https://doi.org/10.1088/1755-1315/1001/1/012033

Sasse, L., Kellner, C., & Kimaro, A. (1991). Improved Biogas unit for developing countries. In *The CAMARTEC biogas unit ; a publication of Deutsches Zentrum für Entwicklungstechnologien - GATE in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH*.

Senger, I., Borges, J. A. R., & Machado, J. A. D. (2017). Using structural equation modeling to identify the psychological factors influencing dairy farmers' intention to diversify agricultural production. *Livestock Science*, *203*, 97–105.

Shafie, S. M., Mahlia, T. M. I., Masjuki, H. H., & Andriyana, A. (2011). Current energy usage and sustainable energy in Malaysia: A review. *Renewable and Sustainable Energy Reviews*, *15*(9), 4370–4377.

Singh, H. V., Bocca, R., Gomez, P., Dahlke, S., & Bazilian, M. (2019). The energy transitions index: An analytic framework for understanding the evolving global energy system. *Energy Strategy Reviews*, *26*, 100382.

Smiley, K. T., Chen, Y.-A., & Shao, W. (2022). Being green in a green capital: Assessing drivers of pro-environmental behaviors in Copenhagen. *Cities*, *122*, 103538.

Solaun, K., & Cerdá, E. (2019). Climate change impacts on renewable energy generation. A review of quantitative projections. *Renewable and Sustainable Energy Reviews*, *116*. https://doi.org/10.1016/j.rser.2019.109415

Tarhini, A., Hone, K., & Liu, X. (2014). Measuring the moderating effect of gender and age on e-learning acceptance in England: A structural equation modeling approach for an extended technology acceptance model. *Journal of Educational Computing Research*, *51*(2), 163–

184.

Tumusiime, E., Kirabira, J. B., & Musinguzi, W. B. (2019). Long-life performance of biogas systems for productive applications: The role of R&D and policy. *Energy Reports*, *5*, 579–583. https://doi.org/10.1016/j.egyr.2019.05.002

Twaha, S., Ramli, M. A. M., Murphy, P. M., Mukhtiar, M. U., & Nsamba, H. K. (2016). Renewable based distributed generation in Uganda: Resource potential and status of exploitation. *Renewable and Sustainable Energy Reviews*, *57*, 786–798. https://doi.org/10.1016/j.rser.2015.12.151

Twerefou, D. K. (2014). Willingness to Pay for Improved Electricity Supply in Ghana. *Modern Economy*, *05*(05), 489–498. https://doi.org/10.4236/me.2014.55046

UBoS. (2009). The Republic of Uganda National Livestock Census Report. In *Statistics*.

UBOS. (2013). Uganda National Household Survey. In *Uganda Bureau of Statistics*.

UBOS. (2016a). *"National population and housing census 2014—main report," Uganda Bureau of Statistics (UBOS): Kampala, Uganda, 2016.*

UBOS. (2016b). *Uganda Demographic and Health Survey*.

UBOS. (2020). The Uganda national household survey. In *Uganda Bureau of Statistics*.

Uhunamure, S. E. (2019). *Development of a Conceptual Framework for Adoption and Sustainable Utilization of Biogas as an Alternative Source of Energy for Emmission*.

Uijen, A. A., Schellevis, F. G., van den Bosch, W. J. H. M., Mokkink, H. G. A., van Weel, C., & Schers, H. J. (2011). Nijmegen Continuity Questionnaire: development and testing of a questionnaire that measures continuity of care. *Journal of Clinical Epidemiology*, *64*(12), 1391–1399.

Vaidy, A. (2020). Stakeholders' Perception About the Effectiveness of Renewable Energy

Subsidy in Nepal: A Review of Biogas Subsidy. *Journal of the Institute of Engineering*, *15*(3), 375–384. https://doi.org/10.3126/jie.v15i3.32225

Walekhwa, P. N., Mugisha, J., & Drake, L. (2009). Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications. *Energy Policy*, *37*(7), 2754–2762. https://doi.org/10.1016/j.enpol.2009.03.018

Wargert, D., & others. (2009). Biogas in developing rural areas. *LTH, Lund University*.

Wassie, Y. T., & Adaramola, M. S. (2019). Potential environmental impacts of small-scale renewable energy technologies in East Africa: A systematic review of the evidence. *Renewable and Sustainable Energy Reviews*, *111*, 377–391.

Wawa, A. I. (2012). *The challenges of promoting and adopting biogas technology as alternative energy source in semi-arid areas of Tanzania: The case of Kongwa and Bahi districts of Dodoma region*. The Open University of Tanzania.

Wawire, A. W., Wangia, S. M., Okello, J. J., & others. (2017). Determinants of use of information and communication technologies in agriculture: the case of Kenya agricultural commodity exchange in Bungoma county, Kenya. *J. Agric. Sci*, *9*(3), 128–137.

Wignaraja, G., Collins, A., & Kannangara, P. (2019). Opportunities and challenges for regional economic integration in the Indian ocean. *Journal of Asian Economic Integration*, *1*(1), 129–151.

Wolff, C., Abigaba, S., & Sternberg Lewerin, S. (2019). Ugandan cattle farmers' perceived needs of disease prevention and strategies to improve biosecurity. *BMC Veterinary Research*, *15*(1), 1–11. https://doi.org/10.1186/s12917-019-1961-2

World Bank. (2021). *Green, Resilient,*.

Zahari, A. R., & Esa, E. (2018). Drivers and inhibitors adopting renewable energy: an empirical

study in Malaysia. *International Journal of Energy Sector Management*.

Zahra, A., Mulema, A. A., Colverson, K. E., Odongo, D., & Rischkowsky, B. A. (2014). *A review of Ethiopia small ruminant value chains from a gender perspective*.

Zhang, H., Gallardo, R. K., McCluskey, J. J., & Kupferman, E. M. (2010). Consumers' willingness to pay for treatment-induced quality attributes in Anjou pears. *Journal of Agricultural and Resource Economics,* 105–117.

Zografakis, N., Sifaki, E., Pagalou, M., Nikitaki, G., Psarakis, V., & Tsagarakis, K. P. (2010). Assessment of public acceptance and willingness to pay for renewable energy sources in Crete. *Renewable and Sustainable Energy Reviews*, *14*(3), 1088–1095. https://doi.org/10.1016/j.rser.2009.11.009

APPENDICES

Appendix 1: GUREC approval

GULU UNIVERSITY

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RESEARCH ETHICS COMMITTEE

15/07/2022

To: SYLIVIA NATANDULA

Gulu University
0772253383

Type: Initial Review

Re: GUREC-2022-209: Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu & Kitgum District, Northern Uganda., 4.0, 2022-07-13

I am pleased to inform you that at the **81st** convened meeting on **17/02/2022**, the Gulu University REC, committee meeting, etc voted to approve the above referenced application.
Approval of the research is for the period of **15/07/2022** to **15/07/2023.**

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **15/07/2023** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by Gulu University REC:

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No.	Document Title	Language	Version Number	Version Date
1	Informed Consent forms	English	4.0	2022-07-13
2	Protocol	English	4.0	2022-07-13
3	Data collection tools	English	3.0	2022-05-20
4	Covid 19 Risk management plan	English	3.0	2022-05-20

Yours Sincerely

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Dr. Gerald OBAI
For: Gulu University REC

Appendix 2: Questionnaire

Version 3.0
Gulu University
Faculty of Agriculture and Environment
Department of Rural Development and Agribusiness

Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu and Kitgum Districts, Northern Uganda

This study is concerned with Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu and Kitgum Districts, Northern Uganda. Being a livestock farmer in this area, you have been selected to participate as a respondent in this study. Any information that you provide will not be disclosed to any other party but will only be used for completion of this study. I therefore humbly request your time and candid response to the following questions.

In case you are consenting to this interview, kindly sign/ thumb-print:
.....

Interviewers Name..... Questionnaire No.....Date.....

District..... Sub-county.....Parish.....Village.....

SECTION A: SOCIO-DEMOGRAPHIC DATA NOTE: Please tick where application

1. Age of Respondent: ..... 2) Sex: i) Male ii) Female

3. Location of HH: i) Rural ii) Urban

4. Marital Status: i) Married ii) Single iii) Widow/Widower iv) Divorced

5. Household Head i) Yes ii) No

6. Age of HH: .....2) Sex of HH: i) Male ii) Female

7) Household Size: ..... (#Children.....#Adult males .....#Adult females.....)

8) How many household members are involved in farming (#Male.....#Female.....#Total.....)

9) Level of education of household head (Years of formal education.....)

10) For the following economic activities, please indicate whether you or any member of your HH is involved in.

Economic activity	**HH undertakes activity**		**Rank of importance if activity (for only those selected) (1=the most important)**	
	Yes	No	Importance for income	Importance for food
Livestock farming				
Crop farming				
Ox-traction				
Civil service				
Causal Labor				

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Skilled occupation				
Others (Specify)				

11) Average monthly income from non-farm activities (Ushs) .....

12. State the crops and/or livestock produced in the last year (2021) – Seasons A and B

Season A	Acreage	Proportion sold (Kgs)	Average Price per Kg (shs)	Total income (shs)
Season B	**Acreage**	**Proportion sold (Kgs)**	**Average Price per Kg (shs)**	**Total income (shs)**

Livestock type	Number (currently)	Management system *(1.Free range, 2.tethering, 3.semi-intensive, 4. intensive)*	# Sold in the last 12 months (specify product)	Average price	Total income
Bull					
Heifer					
Cow					
Calf					
Goat					
Sheep					
Pigs					
Turkey					
Chicken					
Ducks					
Others*(Specify)*					

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13. How do you utilize crop/animal waste on your farm? (*Please tick all that applies*) i) Do not use ii) On-farm manure iii) Livestock feed iv) sale to neighbors iv) Others (*Specify*)
.....

14. Land ownership

1. Land size (Acres)	Owned (Acres).....	Hired (Acres) .....
2.Land tenure system (*For owned land*) i) Customary ii) Private ownership iii) Leased		
3. How did you acquire the land you have? i) Inherited from father ii) Bought iii) Leased iv) Given by a relative v) Other (*Specify*		

15. Household Energy needs and sources

Energy source	**Used by HH** *(please tick all that apply)*		**Source** *1.Trees in the homestead 2.Nearby forest 3.Purchase from vendors 4.Garden refuse 5.Others (Specify)*	**Distance to source** *(km)*	**Time to source** *(In minutes)*	**Quantity used per month**	**Average cost per month**
	Light	cooking					
Firewood							
Charcoal							
Briquettes							
LPG							
Electricity							
Solar							
Paraffin							
Torch							

16. Do you use Energy Saving Cooking stoves (ESC)? i) Yes ii) No

17. How available is water in your place? i) Readily available ii) In short supply

18. What is the distance to your domestic water source? *(In km)*.....Time taken *(in minutes)*.....

19. Source of water i) River/Stream ii) shallow well iii) Borehole iv) Community stand v) Rain tank vi) Municipal tap (Inside home) vii) Municipal tap (Outside home) viii) Others (*Specify*).....

SECTION B: PERCEPTIONS TOWARDS DOMESTIC BIOGAS SYSTEMS

1. Have you heard about biogas as an alternative energy source? i) Yes ii) No

a) If yes, what was the source of information? i) NGO ii) Neighbor iii) Media

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iii) Government extension worker iv) Private company v) Other *(Specify)*

.....

b) Since you were informed about biogas technology as an energy source, have you thought of trying it?

i) Yes ii) No

c) If no, Why? .....

d) Have you participated in any biogas project before 1. Yes 2. No

e) If yes (i) Do you have access to biogas technicians/experts who construct biogas plants 1. Yes 2. No

f) Do you think you have sufficient animal waste to run a biogas plant? 1. Yes 2. No

2. Kindly tick the extent to which you agree or disagree with the following statements about you think of a domestic biogas system. (1=strongly Disagree, 2= Disagree, 3= Undecided, 4= Agree, 5= Strongly Agree)

Biogas Attributes	**SD**	**D**	**UN**	**A**	**SA**
	1	**2**	**3**	**4**	**5**
Installation cost of biogas is not affordable^{R}					
Maintenance costs after installation are low					
Biogas could solve the problem of fuel shortage					
Biogas saves time that would be spent collecting fire wood					
Use of biogas can reduce the rate of deforestation					
Biogas affects the cooking quality^{R}					
Use of biogas improves health					
Biogas slurry improves soil fertility					
It is not easy to understand and operate biogas^{R}					
It is not labour intensive					
Using the technology improves standards of living					
The technology is not durable^{R}					

Kindly tick the extent to which you think of these as limitations to uptake of domestic biogas systems (1=strongly Disagree, 2= Disagree, 3= Undecided, 4= Agree, 5= Strongly Agree)

	SD	**D**	**UN**	**A**	**SA**
	1	**2**	**3**	**4**	**5**
Lack of awareness and knowledge about the technology					
High costs of installation					
Difficult to operate					
Unavailability of feedstock					
Unavailability of water					
Limited labor					
High maintenance costs					

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Difficult to get maintenance services					
Does not produce enough energy					
Lack of subsidies					
Limited access to credit					
Availability of alternative energy sources					
Biogas requires intensively livestock production					

Do you think there are foods that cannot be prepared using biogas? i) Yes ii) No

If yes, which ones, and why

.....

.....

.....

.....

Do you think the government/NGOs have done enough to promote biogas i) Yes ii) No

What (else) can they do to sustainably increase biogas uptake?

.....

.....

.....

.....

SECTION C: WILLINGNESS TO PAY FOR DOMESTIC BIOGAS SYSTEMS

Biogas can be produced from any waste that can rot e.g Dung of all animals, Human waste, Kitchen and crop residues.

To generate the gas, a biodigester is used. A biodigester is a big container that is buried under the ground. (fixed dome)

Waste is mixed with water and introduced to the digester where it is broken down by bacteria and gas is produced.

With an equivalent of 2 cattle, you can produce gas to cook at least 4 hours and the digester lifespan is up to 25 years

Benefits of using a domestic biogas system include:

- *Provides energy for cooking*
- *Saves time that you spend collecting wood fuel. This time can be used to do other things for instance farming*
- *Helps protect the environment because you cut fewer trees for fire wood*
- *Its good for your health because you do not inhale smoke like when you are using open fire for cooking and lighting*
- *The bio-slurry can be used as fertilizer for soil improvement*

Are you willing to pay for a domestic biogas system? i) Yes ii) No

Why

?.....

.....

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If initial installation of a digester costs 2,000,000 UGX, would you be willing to pay for it? i) Yes ii) No

If not, how much would you be willing to pay? .....

Bid amount	Yes	No
1,800,000		
1,600,000		
1,400,000		
1,200,000		
1,000,000		
800,000		
600,000		
400,000		
200,000		

How much are you willing to pay per year for the maintenance of the digester?
.....

Thank you for your time, God bless you!

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Appendix 3: Informed consent

INFORMED CONSENT DOCUMENT
VERSION 4.0

Title of the study: PERCEPTIONS AND WILLINGNESS TO PAY FOR DOMESTIC BIOGAS SYSTEMS IN GULU & KITGUM DISTRICT, NORTHERN UGANDA.

Investigator(s): NATANDULA SYLIVIA

Institution(s) GULU UNIVERSITY

Introduction

Hello, my name is Natandula Sylivia, a masters' student /researcher from the Department of Rural Development and Agribusiness, Faculty of Agriculture and Environment, Gulu University, Uganda. I am collecting data on the topic: **"Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu & Kitgum District, Northern Uganda."**

This study is purely academic and purposely intended to help researchers understand the factors influencing Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu & Kitgum Districts. You have been selected randomly to participate in this survey. Please note that the information provided by you will be treated confidential and there will be no way to identify you as the one who gave specific information. I would be glad if you could spare some time (approximately 30 minutes) to answer our questions.

At the end of the interview, you will receive a bar of soap as compensation for the time spent participating in this study

Thank you

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A brief description of the sponsors of the research project

This study is funded by CARITAS Gulu in Collaboration with Gulu University.

Purpose:

The study seeks to Investigate the factors influencing Perceptions and Willingness to Pay for Domestic Biogas Systems in Gulu & Kitgum District, Northern Uganda The study will serve as a suitable policy tool for stakeholders working to reduce energy poverty for example

Government,NGOs, Private sector actors and other reseachers. It will also avail farmers with information ondomestic biogas systems as an alternative renewable energy source which may help to makedecisions that will enhance sustainable economic growth of the country. The discoveries of thestudy will attract the attention of researchers, as well as policy makers and private sector

Procedures:

Your participation in this study will involve answering the questions while filling in the questionnaires as requested.

Who will participate in the study?

You have been chosen to participate in this study because you are a livestock farmer. The interview will last for approximately thirty minutes or less and the participants will be 250 with you inclusive.

Risks/discomforts:

There is no foreseable risk of harm or discomfort that will arise from your participation in this study. The only risk or discomfort will be the inconvenience in terms of time spent during the interview and the risk of contracting or spreading COVID-19 during the interview. To minimize this risk, both you and the enumerator will be required to property wear face masks and sit two meters apart. In addition, all materials handed to you during the interview will be sanitized.

Benefits:

Benefits will prevail after the researchers have compiled a report of findings and concerned bodies react appropriately. The research participants will get feedback on findings and progress of the study, and any new information that affects the study participants (including incidental findings) will be made available to research participants.

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Confidentiality:

Your identity will not be revealed to anyone as we shall only use codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be

protected by password and hard copy files will be kept under lock and key. Confidential information will only be accessed by the principal investigator.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost:

There will not be any additional cost incurred as a result of participating in this study.

Questions:

If you have any questions related to the study or your rights as a research participant, you can contact the principal investigator, NATANDULA SYLIVIA on telephone 0772253383 or via email at sylvianatandula@gmail.com

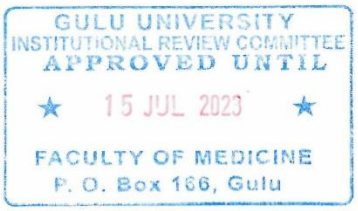
Statement of voluntariness:

Participation in the research study is voluntary and you may join of your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, Dr. Gerald Obai Tel: No., 0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and Technology, on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

.....has described to me what is going to be done, the risks, the benefits involved, and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity

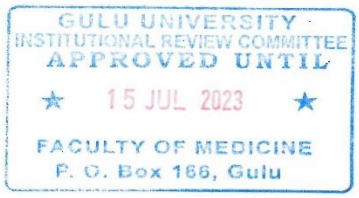


will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name of participant…… Signature/Thumbprint…….... Date…….

Name of witness……..…. Signature……..Date……..

Name of interviewer……....Signature……..…Date…….



Appendix 4: Translated informed consent form

Version 3.0

INFORMED CONSENT DOCUMENT

Title of the study: PERCEPTION AND WILLINGNESS TO PAY FOR DOMESTIC BIOGAS SYSTEMS IN GULU AND KITGUM DISTRICTS, NORTHERN UGANDA.

Investigator(s): NATANDULA SYLIVIA

Institution(s) GULU UNIVERSITY

Nyute:

Amoti baa,

An nyinga Natandula Sylivia, atin kwan me Gulu University ijyange me dongo lobo me kin paco kede biacara ame tye idul me pur kede kan orumu waa.

Kwed eni, obedo pi chobo lokom kwan keken ki konyo lukwed mogo mingan yoo mogo ma weacko loko tem ki bedo angonya pa danno miculu pi maach maya ki ikom yamo/gami mutop makiyuubu ikin gangi mai Gulu ki Kitgum district. Itye dano acel makiyero mikonyowa mi gamo lapeny magi. Bed kingaeck ni lagam wang mai ibi mio we bi cwalo calo mung, wek lok wang mai ibi mio pee odug ki kit yoomo keken bot inn. Cwinya obi bedo yom kaibi mina kara ni manok (maromo dakika 20-30) mi gamo lapeny w ani.

Yi agiki me apeny man, obi mii cabun bar acel me pwoc pi cawa ni kede tami I kwan man.

Apwoyo matek.

Ngnec acegocego akwo joo ame oculu pi ikweda man

Ikeweda man jo ame oculu pire obedo dul ame olwongo ni, Caritas Gulu karacel kede Gulu University

Icwil me kwan man:



kwan man, neno me kwedo yoo mogo ma weacko loko tem ki bedo angonya pa danno miculu pi maach maya ki ikom yamo/gami mutop makiyuubu ikin gangi mai Gulu ki Kitgum district matye iyunkumalo me lobo Uganda. Kwan eni, obi bedo dul acel ikom cik meamoka mi dwoko can mi maach yamo calo ki Uganda, dul ma pe gengea ikom gamenti (NGO), dul ma chun kekenge, ki lukwed mogo. Obi miyo lupur ngeach ikom maach maya ki ikom yamo/gami mutopo makiyuubu ikin gang, ma obi leyo kakar maacgi mukene mubikonyo metingo kero me biacara ilobo man. Lok pa kwan man obi kwanyo miti pa lukwed wakii pa lumok cik.

Yore ame atic kede:

Tici iyi ikweda man bino bedo me gamo apeny kun ipongo iyi papara ame obino miyi

Joo ame abedo iyii ikweda man:

Inn, ki yeri me konyo gamo lapeny man pien ibedo lapur ma gwoko dook. Lapeny obibedo maromo pi dakika priarariyo ki dano 250 med ki in ikomgi.

Peki ame yaa ikom ikweda man:

Peko moro ame bino yaa iyi ikweda man pe nikwanyo kono ka cawa nii ame ibino miyo. Pi gwoke ki ikom too korona kara ma wa bi bedu ka mini lapeny, in ki lapeny peny wu bi ruko laboo dog ki wom. Dok gi mo kiken ma wait mini ikare man me kwed/ nyo minu lapeny ni ducu ki kiru ne.

Ber pa ikweda man:

Adwogi me kwed man obi naen engea lukwed coyo waraga ki miiyonae bot luloch mu poore. Lumi ngeach obi ngoo adwogi me kwed man eka bene ngeach mogo mukene melub kwan eni.

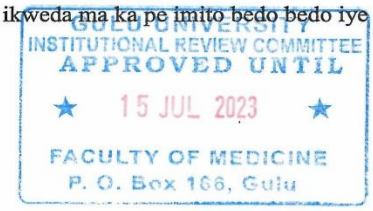
Gwoko imung:

Imung ikom ngat acelacel ame bino miyo tamere pe obino kelo oko kan aler

Onyo:

Itye kede twero me kwero miyo tami ikom ikweda ma ka pe imito bedo bedo iye

cul



Pe tye cul Kitgum kike ame bino yaa iboti wek ibed ikweda man

Apeny

Ka itye kede apeny omore kiken akwako ikweda man, itwero goyo cim bot aloo wii ikweda man I nuba cim man NATANDULA SYLIVIA 0772253383 onyo itwero cwalo kwena email

Lok akwako kop ikom jale me miyo tami:

Miyo tam ikom ikweda man dic pee iye dong itye agonya me miyo tami onyo pe

Ka itye kede peko moro onyo twero ni oturu ikare me ikweda man itwero miyo ngec bot Adit alo kop me pwonyore kede ikweda I Gulu university, Dr. Gerald Obai Tel: Nama cim, 0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; onyo imi ngec bot Uganda National Council for Science and Technology, ame tye iw plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

Yeo:

.....Omyia angeo ngo ame bino timere, peko abini yaa iyee, ber ikweda man,kede twero na akwako ikweda man. Anyang aber dong amoko tam ani aye bedo ikin joo ame bino miyo tam gi iyi ikweda man.

Nying agam apeny ..... Signature/Thumbprint.....ninodwe .....

Nying acaden .....Signature .....ninodwe .....

Nying apenya apeny .....Signature..... ninodwe .....

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Appendix 5: Measures for the prevention and control of risk of spread of COVID-19 during the implementation of the research

Measures for the Prevention and control of risk of spread of COVID-19 during the implementation of research

Study Title: PERCEPTIONS AND WILLINGNESS TO PAY FOR DOMESTICBIOGAS SYSTEMS IN GULU & KITGUM DISTRICT, NORTHERN UGANDA

Principal Investigator (s): NATANDULA SYLIVIA

Introduction:

The novel Coronavirus is transmitted from human to human through droplets and direct or close personal contact with an infected individual

Novel Coronavirus signs of infection include respiratory symptoms, fever, cough, shortness of breath and breathing difficulties. In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure and even death

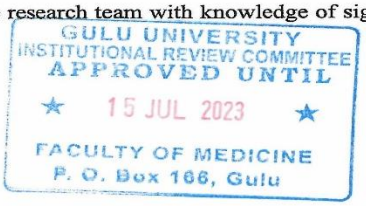
Implementation of the prevention and control measures

In the implementation of the research activities, the investigators are committed to ensuring the safety of its research team, research participants and communities where the study will be conducted. The study team undertakes to comply with the Standard Operating Procedures issued by the Ministry of Health, and presidential directives to mitigate against the risk of infection of COVID-19, rapidly detect and effectively respond to any COVID-19 case that may occur in the process of carrying out the study, screening, face covering, physical distancing, and good hand hygiene.

Procedures to be followed during the implementation of the research.

Prior to data collection and Training

1. **Health guidance:** There will be training sessions dedicated for COVID-19 sensitization and awareness, to equip the research team with knowledge of signs and symptoms of the

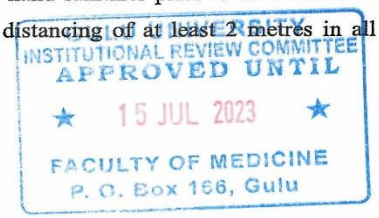


COVID-19, and preventive measures such as hand hygiene before placing and removing the mask, as well as storage of the mask, social distancing. The research team will circulate notices, posters, charts on common signs and symptoms of COVID-19 as provided by the Ministry of Health, and develop and/or use existing plan for the appropriate referral pathway for identified and/or suspected cases.

2. **Personal Screening:** All researchers, research assistants, research participants and any other individuals engaged in research activities will screen temperature daily for fever. Screening for temperature will be carried out during planning meetings, trainings, community outreach. Any individual found with COVID 19 symptoms will be withdrawn and referred to the COVID – 19 task force for further assessment and management. The withdrawn individual will be allowed to return only if they present a valid certification of their COVID-19 status showing negative result
3. **Wearing face coverings:** All researchers and research assistants and any other individuals engaged in research activities that require interaction with fellow researchers or research participants or the community member will have to wear a face mask that fully covers the mouth and nose at all times. The study will provide face masks for individuals who do not have.
4. **Physical Distancing:** There will be social distancing during the training, meetings, community outreach of at minimum of 2 metres. During breaks, the team will not be allowed to congregate in common areas.
5. **Good hygiene:** All team members will be required to wash their hands or use hand sanitizers before and after entering the training room, and other common areas. Hand washing equipment shall be supplied and made available at all times. All surfaces and equipment shall be sanitised frequently.

During data collection

1. **Personal Protective Equipment (PPE):** All research assistants involved in tracing of respondents and in in-person interviews and research participants will use PPE including a properly fitted face mask. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Handshakes and hugging are prohibited. Physical distancing of at least 2 metres in all research related activities shall be observed.

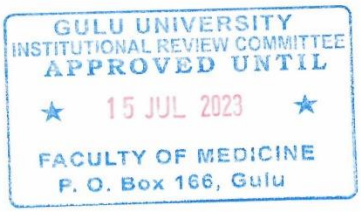


2. **Consent Process:** The Researcher /Research assistants will observe social distancing when taking consent (while 2 metres apart) upon arrival to the participant. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Participant will then be sensitized on covid-19 and presented with preventive measures.
3. **Equipment sanitization:** shared devices used to record or capture data shall be sanitized regularly.

During Dissemination/Community engagement

1. **Community Engagement:** The research team shall carry educational materials on prevention of COVID-19 in Acholi, A language understood by most of the participants. These materials shall also have visual images to support understanding. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Screening for temperature will be carried out prior to conducting community engagements.
2. **Equipment sanitization:** shared devices and any other materials used during community engagements shall be sanitized regularly.

The preventive and control measures will continuously be reviewed based on new information and guidelines communicated by the Ministry of Health



Appendix 6: Correlation matrix

	Paraff~e	Tropic~t	Livest~t	NewInc~e	LnTrLv~t	A~Tech~s	Percep~e	Fire~nce	YesPar~s	Readil~r	RuralL~n	Female~w
ParaffinUse	1.0000											
TropicalLi~t	-0.1741	1.0000										
LivestocMgt	-0.1634	-0.1841	1.0000									
NewIncome	-0.1690	0.2289	0.0113	1.0000								
LnTrLvUnit	-0.2217	0.8337	-0.0959	0.2258	1.0000							
AccessTech~s	0.0391	0.0157	-0.1850	0.0609	-0.0499	1.0000						
Percepscore	-0.1588	0.1641	0.0483	0.1622	0.1762	0.2462	1.0000					
Firewood_D~e	0.0395	0.0060	0.0048	-0.0454	0.0396	-0.0143	0.0752	1.0000				
YesPartbio~s	-0.0511	0.1164	-0.0258	0.1171	0.0782	0.4256	0.1754	0.1447	1.0000			
Readilyava~r	-0.0598	0.0142	-0.1582	-0.0849	-0.0362	0.2011	0.1464	0.1137	0.0918	1.0000		
RuralLocat~n	0.0450	-0.0585	-0.0611	-0.1489	-0.0426	0.0017	-0.2173	-0.0700	-0.1399	-0.0809	1.0000	
FemaleGend~w	-0.0373	-0.0653	-0.0695	0.1072	-0.1093	-0.0860	-0.2841	-0.0844	-0.0703	-0.0695	0.0863	1.0000

Appendix 7: Results for Logistic model regression

```
. logit CatPercept EnoughWaste Partbiogas NewIncome LnAge AccessTechnicians ReadilyavailableWater TetheringLivMgt MarriedMS RuralLocation MaleGender

Iteration 0:   log likelihood = -172.89459
Iteration 1:   log likelihood = -142.95931
Iteration 2:   log likelihood = -142.61534
Iteration 3:   log likelihood = -142.61375
Iteration 4:   log likelihood = -142.61375

Logistic regression                             Number of obs     =        250
                                                LR chi2(10)       =      60.56
                                                Prob > chi2       =     0.0000
Log likelihood = -142.61375                     Pseudo R2         =     0.1751
```

CatPercept	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EnoughWaste	.788517	.3396279	2.32	0.020	.1228586	1.454175
Partbiogas	.3908258	.4326159	0.90	0.366	-.4570858	1.238737
NewIncome	.2416483	.1237931	1.95	0.051	-.0009817	.4842783
LnAge	-.4157874	.4278601	-0.97	0.331	-1.254378	.4228029
AccessTechnicians	1.492429	.4057242	3.68	0.000	.6972238	2.287633
ReadilyavailableWater	.3035752	.3480075	0.87	0.383	-.3785069	.9856572
TetheringLivMgt	1.096178	.3847911	2.85	0.004	.3420016	1.850355
MarriedMS	.6741895	.3200817	2.11	0.035	.0468408	1.301538
RuralLocation	-.9778052	.3210325	-3.05	0.002	-1.607017	-.348593
MaleGender	-.625814	.314017	-1.99	0.046	-1.241276	-.0103521
_cons	-3.103746	2.497382	-1.24	0.214	-7.998524	1.791032

Appendix 8: Results for Probit with standard errors

```
. probit WTPdummy NewIncome LnTrLvUnit AccessTechnicians Percepscore Firewood_Distance YesPartbi
> ogas ReadilyavailableWater RuralLocation FemaleGenderNew

Iteration 0:   log likelihood = -81.270743
Iteration 1:   log likelihood = -39.631599
Iteration 2:   log likelihood = -24.715423
Iteration 3:   log likelihood = -23.022367
Iteration 4:   log likelihood = -22.962943
Iteration 5:   log likelihood = -22.962737
Iteration 6:   log likelihood = -22.962737

Probit regression                                 Number of obs     =        250
                                                  LR chi2(9)        =     116.62
                                                  Prob > chi2       =     0.0000
Log likelihood = -22.962737                       Pseudo R2         =     0.7175

------------------------------------------------------------------------------
             WTPdummy |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------------+-------------------------------------------------------------------
           NewIncome |   .1383373   .0937507     1.48   0.140    -.0454107    .3220853
          LnTrLvUnit |   .8309317   .5012685     1.66   0.097    -.1515365      1.8134
   AccessTechnicians |  -1.927068   .7362102    -2.62   0.009    -3.370014    -.484123
         Percepscore |   29.11075   6.686016     4.35   0.000      16.0064     42.2151
   Firewood_Distance |  -.1038429    .044658    -2.33   0.020    -.1913709   -.0163149
       YesPartbiogas |   .9804815   .7220506     1.36   0.174    -.4347117    2.395675
ReadilyavailableWater |  -3.694807   1.079451    -3.42   0.001    -5.810492   -1.579123
       RuralLocation |   1.188361   .5611877     2.12   0.034     .0884535    2.288269
     FemaleGenderNew |   1.421813   .5567697     2.55   0.011     .3305647    2.513062
               _cons |  -14.66026   3.760686    -3.90   0.000    -22.03107   -7.289456
------------------------------------------------------------------------------
```

Appendix 9: Results for probit with marginal effects

```
. margins,dydx(_all)

Average marginal effects                        Number of obs     =        250
Model VCE    : OIM

Expression   : Pr(WTPdummy), predict()
dy/dx w.r.t. : NewIncome LnTrLvUnit AccessTechnicians Percepscore Firewood_Distance
               YesPartbiogas ReadilyavailableWater RuralLocation FemaleGenderNew

------------------------------------------------------------------------------
                     |            Delta-method
                     |      dy/dx   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
           NewIncome |   .0069643   .0045702     1.52   0.128    -.0019932    .0159218
         LnTrLvUnit |   .0418315    .024299     1.72   0.085    -.0057938    .0894567
   AccessTechnicians |  -.0970141   .0320537    -3.03   0.002    -.1598383   -.0341899
         Percepscore |   1.465518   .1851983     7.91   0.000     1.102536      1.8285
   Firewood_Distance |  -.0052277   .0020106    -2.60   0.009    -.0091685    -.001287
       YesPartbiogas |   .0493602   .0348351     1.42   0.156    -.0189153    .1176357
ReadilyavailableWater |  -.1860071   .0394263    -4.72   0.000    -.2632812    -.108733
        RuralLocation |   .0598255   .0260611     2.30   0.022     .0087466    .1109044
     FemaleGenderNew |   .0715781   .0245267     2.92   0.004     .0235067    .1196495
------------------------------------------------------------------------------
```

Appendix 10: Results for Tobit regression

```
Tobit regression                                Number of obs     =        250
                                                LR chi2(9)        =      70.81
                                                Prob > chi2       =     0.0000
Log likelihood = -3317.3262                     Pseudo R2         =     0.0106

------------------------------------------------------------------------------
    WTP_Installation |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
          MaleGender |  -278983.6   81903.49    -3.41   0.001    -440321.7   -117645.4
        ParaffinUse |  -153551.9   86376.67    -1.78   0.077    -323701.5    16597.75
          NewIncome |   32700.49   22976.54     1.42   0.156    -12559.98    77960.96
         LivestocMgt |  -78515.25   87251.36    -0.90   0.369    -250387.9    93357.37
TropicalLivestockUnit |   32621.26   15970.67     2.04   0.042     1161.346    64081.18
         HHHead_Educ |   10609.98   9000.474     1.18   0.240    -7119.664    28339.62
              NewAge |   72418.76   131066.6     0.55   0.581    -185763.5      330601
       YesPartbiogas |   164946.8   92218.25     1.79   0.075    -16709.94    346603.5
              lambda |  -633583.7   246297.7    -2.57   0.011     -1118755   -148412.6
               _cons |   92741.65     615328     0.15   0.880     -1119366     1304849
---------------------+--------------------------------------------------------------
              /sigma |   552478.1   26514.16                      500249    604707.2
------------------------------------------------------------------------------
           25  left-censored observations at WTP_Instal~n <= 0
          225     uncensored observations
            0 right-censored observations
```

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