Investigation into the development potential of biogas technologies for small-scale farmers in Taita Taveta, Kenya

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Affirmation

Hereby, I formally declare that I have developed and written the enclosed thesis without illegitimate help of a third party and that no other than the indicated aids have been used for its completion; all thoughts from other sources that have been used literally or indirectly are marked as such. The thesis has not been submitted to any other examination committee in this or a similar form.

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Abstract

Rising energy prices of the 1970s triggered alternative energy research and development globally. Biogas technology took off in the agricultural sector of developed nations, but biogas dissemination failed to spread throughout most developing nations. The failure was largely due to the high initial investment costs and lack of a widespread knowledge base.

In Kenya, approximately 90% of rural households rely on traditional biomass stoves for cooking. Cooking with traditional biomass stoves leads to environmental, health, economic and gender hardships in the local community. Kenya has been relatively slow to adopt biogas throughout most regions, including Taita Taveta county. Taita Taveta county has a high volume of underutilized animal and plant waste that could otherwise provide environmental, health, economic and social benefits to the region.

As a part of this research, a questionnaire with 34 questions was asked to 200 rural households throughout Taita Taveta County. The questions were meant to determine the regional biogas capacity, the level of biogas knowledge, and the potential benefits that biogas dissemination could provide to the region. The results from the questionnaire estimated that approximately 15,000 households can provide the financial and substrate capacities required for biogas adoption. Biogas development in the region can provide great benefit through reducing the reliance on traditional biomass and improving the welfare of rural Kenyans.

Keywords: biogas digester, cook stove, Kenya, renewable energy, rural, small-scale farming, Taita Taveta

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List of Abbreviations

ABPP	African Biogas Partnership Programme
BPCCP	Biogas Producer-Consumer Combination Problem
CEDAW	Convention on the Elimination of all Forms of Discrimination against Women
CEMEREM	Centre of Excellence for Mining, Environmental Engineering and Resource Management
CIDP	County Integrated Development Plan
FAO	Food and Agriculture Organization (Of the United Nations)
FBS	Flexi Biogas System
GERP	Gender and Energy Research Programme
HAP	Household Air Pollution
HIV	Human Immunodeficiency Virus
IAP	Indoor Air Pollution
IFAD	International Fund for Agricultural Development
KENDBIP	Kenyan National Domestic Biogas Programme
KSH	Kenyan Shillings
PFM	Participatory Forest Management
RQ	Research question
SDG	Sustainable Development Goals
TTCG	Taita Taveta County Government
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
WHO	World Health Organization

1 Introduction

1.1 Background

Biogas technology usage was first documented in the 1850s in India and New Zealand. Shortly after this time period, this technology was recorded in the UK where the biogas fuel was used to light street lamps in Exeter. The first reported commercial usage occurred in China in 1921, around the same time that the first German wastewater treatment plant was connected to the public gas supply. In 1950, the first large-scale agricultural biogas plant began operation in Germany (Templeton & Bond, 2011). In the 1970s, stimulated by the energy crisis, biogas technology spread rapidly throughout both developed and developing nations. Throughout the 1980s and beyond, biogas technology continued to succeed in developed countries and in large-scale industrial sectors, but the success and dissemination of biogas technologies throughout the developing world rapidly declined. Much of this decline is attributed to a lack of success maintaining the operability of biogas plants. By the mid-1980s only 50 to 75% of the previously installed biogas plants were functioning in many developing nations (Ni & Nyns, 1996).

Kenya, like much of the African continent, did have large volumes of international investment and development of biogas technologies. The first biogas digester was installed in Kenya in 1957 and the technology continued to spread through NGO initiatives and through foreign government aid programs (Adoyo, et al., 2007). While these projects were widespread throughout Kenya in the 1970s and 1980s, the technology didn’t disseminate as well as expected. Much of the market penetration failure is blamed on the high construction and maintenance costs, as well as the lack of local experience in constructing, maintaining, and operating the units (Blanchard & Hamid, 2018).

Currently, the usage of biogas in Kenya is far less than 1% (Adoyo, et al., 2007). Market penetration has remained low even with promotional efforts by the Kenyan Ministry of Energy, which in 2004 pledged to promote domestic biogas technology growth. Additionally, many of the previously constructed biogas plants in Kenya are operating below capacity, are dormant or are no longer capable of operating. The

Kenyan Ministry of Energy estimates that there are only approximately 20,000 functioning biogas systems in the country (Kenyan Ministry of Energy, 2018).

1.2 Motivation for research

Biogas technology adoption in Kenya has great economic, health and environmental benefit potential due to the high volume of underutilized animal dung and the heavy reliance on biomass fuels. Three quarters of Kenya's population live in rural areas and approximately 90% of those rural households use firewood as their predominant cooking source (Ndegwa, G., Breuer, T., & Hamhaber, J., 2011). Biogas adoption would allow for decreased reliance on traditional biomass cookstoves and provide the additional benefits of enhanced fertilizer. This research aims to take a closer look at a small fraction of the 1.25 million households which are estimated to be able to support biogas technology in Kenya (Heegde & Sonders, 2007).

Switching from biomass cook stoves to biogas cook stoves is a great socioeconomic and environmental opportunity due to the large health, environmental and socioeconomic costs associated with traditional biomass cooking. Since biomass cook stoves use mostly fire wood or charcoal, the resulting fuel wood collection leads to increased deforestation and potential losses of ecosystem services. Additionally, inhaling smoke while cooking with traditional biomass cook stoves has many documented health and environmental effects. A 2012 World Health Organization (WHO) report that traditional biomass cooking stoves are responsible for approximately 4.3 million deaths annually, far more than either malaria or HIV (WHO, 2012). Taita Taveta County is an excellent potential study area due to most of the population living in rural areas and the presence of a resource university which can provide an additional knowledge base and support structure.

1.3 Linkages to CEMEREM

A project for the development of a Centre of Excellence for Mining, Environmental Engineering and Resource Management (CEMEREM) began in 2016 as a joint project between Taita Taveta University, Freiberg University of Mining and Technology, and the University of Applied Sciences Dresden. The primary objective of the project is to create a world class facility and develop teaching and research programs that can be used to train resource managers in Africa. Another goal of the project is to facilitate scientific and cultural exchange between Kenya and Germany.

This biogas research project was done as a small part of the CEMEREM project and coincides with the shipment and installation of two smart biogas plants at each the two Taita Taveta University campuses. The goal of the survey was to discover the level of knowledge, the interest and the capability for the local community to adopt the technology.

1.4 Research Questions

Question 1: When considering the literature, what are the relevant components to developing biogas technology in developing regions, and what barriers, successes and potential benefits exist?

Question 2: In the results of the Taita Taveta County biogas questionnaire, which of the barriers, successes and potential benefits exist?

Question 3: What can we learn about the outcomes, how can we move forward to assure successful biogas dissemination throughout the region with the maximum benefit?

1.5 Scope and Structure of Study

The study was done in Taita Taveta, Kenya, which has a population of approximately 300,000 spread over an area of 17,000 km^2. The region consists of several tribes and languages and a wide variety of geographical differences ranging from savannah and bush woodland in the lowlands to the cloud forests that make up the highlands (Masawi, 2015). The 200-person survey was conducted throughout the 20 wards in Taita Taveta County. The target population for the survey was all rural households. The survey consisted of 34 questions targeting both quantitative and qualitative data pertaining to the responders understanding, interest, potential benefit from, and capacity for adopting biogas technologies.

1.6 Thesis Structure

The research paper is structured into seven individual sections. Following the introduction in chapter 1, chapter 2 introduces the reader to a thorough literature review that seeks to answer research question (RQ) 1. Chapter 3 further expounds on RQ 1 while targeting the Taita Taveta region to introduce the reader to the area. Chapter 4 begins to answer RQ 2 with the presentation of the research methodology used in the questionnaire. Chapter 5 further answers RQ 2 by presenting all the data collected in the questionnaire. Chapter 6 seeks to answer RQ 3 by providing an analysis and discussion of the results compared with the information revealed in the literature review. Finally, chapter 7 further expounds on RQ 3 by providing a conclusion and recommendations.

2 Literature Review

2.1 Introduction

This chapter introduces the reader to pertinent research already done in the relevant sectors. The aim of this section is to give the reader a better understanding of the research backdrop used for the development of the research questionnaire and the writing of this thesis. The literature review will focus on those papers which provide the most information and context to the research paper. The subset of literature that will be explored will cover the following relevant subject areas, with an increased focus given to those papers written in East Africa other nearby nations:

1. Biogas Development
2. Biogas and the Environment
3. Biogas and Policy
4. Biogas and Health
5. Biogas and Gender
6. Biogas and Socioeconomics
7. Challenges to Biogas Acceptance

All material covered here comes from governmentally sponsored research projects, United Nations reports, or from peer reviewed journal entries or papers. This section serves to fill in any knowledge gaps before introducing the reader to the data gathered from the research conducted in Taita Taveta.

2.2 Biogas Development

2.2.1 Technology

Biogas originates from bacteria that is released from the natural bio-degradation of organic matter under anaerobic conditions. Biogas is predominately methane (40-70% volume) and carbon dioxide (30-60% volume). While natural generation of biogas is an important part of the carbon cycle, methanogens can also be used with the assistance of technology to produce biogas energy through usage of a biogas digester. The calorific value of gas obtained through biogas technology depends largely on the temperature, pressure, water-vapor content, and the substrate input. In addition, the appliances and burners efficiency that is used to harness the biogas technology is important. Biogas digesters produce not only biogas, but also a slurry or sludge that can be used as a fertilizer due to its relatively high nitrogen, phosphorus and potassium content. All biogas plants have several key components, a biogas digestion chamber, an inlet for substrate, an outlet for slurry and a gas collection chamber. Apart from these similarities, there are also large differences and adaptations that can be made to biogas plants to make them perform better depending on the local conditions (Krossman et al., 1999).

While some suggest that biogas was used as early as the 10^{th} Century B.C. in Assyria, the earliest documented biogas digesters come from the mid-nineteenth century in New Zealand and India. Biogas was first transferred to Europe in the 1890s. Up until the 1970s biogas systems were only infrequently applied in both large-scale agricultural plants and in smaller-scale household waste projects. Due to increasing energy prices in the 1970s, people began researching alternative energy sources which led to a rapid expansion of both knowledge about and application of biogas plants (Templeton & Bond, 2011). Following this energy crisis, there was a sharp increase in interest in biogas technology, especially in the developing world.

The biogas energy sector grew extremely rapidly throughout the 1970s to mid-1980s with most of the growth being in the construction of fixed dome and floating drum biogas systems throughout Asia, Latin America and Africa. According to research from Ji-Qin Ni & Edmond-Jaques Nyns, by 1993, there were 6 million digesters installed in 53 developing nations (Ni, J. & Nyns, E.J., 1993). In Kenya, however, the growth was not quite as rapid with it being estimated that there were only 850 household biogas plants installed in Kenya by 1995, with only 25% of those plants being operational (Gitonga, 1997).

Biogas development in developing nations did lead to many problems early on. While evidence of this has been found in many countries, one of the most powerful statistics comes from the World Energy Conference in 1989. Research showed that although there were approximately 7 million biogas digesters installed in China from 1975 to 1979, only 3 million were ever operational. This led to the Chinese governmental policy favoring quality rather than quantity of biogas digesters. The number of digesters produced per year was reduced greatly, but their longevity was increased (World Energy Conference, 1989).

This problem did not just occur in China, rather it occurred in most of the developing world with the diffusion rates dropping rapidly after the mid-1980s. In Latin America, the yearly installation rate decreased seven-fold from 1982 to 1992. Much of this drop is due to the discovery that only 50 to 75% of the biogas plants were still in operation after just a few years (Caceres & Chiliquinga, 1986). This concept will be revisited further in the theory section following this technology development section.

Historically, the most frequently installed biogas systems have been the fixed dome biogas system and the floating drum biogas system, both of which were mostly restricted to only using cow or pig dung early on. These two systems are both material and labor intensive as they are installed underground and use bricks, concrete, and potentially even steel. Due to the material costs, installation costs, and permanence of these digesters, they require a large initial investment as well as land security (Sovacool, Kryman & Smith, 2014). These biogas plants, when installed correctly, have been historically reliable and require little maintenance, however, with a lack of proper maintenance, their productivity and operability, as observed by Templeton and Bond, can be greatly reduced (Templeton & Bond, 2011).

More recently, to increase the dissemination rates, new portable systems have been developed with lower initial investment costs and more substrate flexibility. An example of this type of system is the flexi biogas system (FBS), which was developed in 2011 in a partnership of the International Fund for Agricultural Development (IFAD) and Biogas International. The FBS is portable and includes just four key parts: input and output pipes, a reinforced plastic digester bag, transportation piping, and a plastic “greenhouse” covering. Besides the portability and lower price point, the system can be supplemented with vegetable waste in addition to the dung after the bacterial process has been catalyzed, thus broadening the range of the users who would be able to use the technology. Figure 1 is a comparison from Sovacool et al. (2014) between the traditional fixed dome and floating drum systems and the newer FBS. While the technology hasn’t yet had time to prove itself, a study from 2014 focusing on the successes and failures of the FBS system in Kenya was completed by Sovacool et al., which includes a comprehensive project review as well as in-country interviews (Sovacool, Kryman & Smith, 2014).

	Fixed dome biogas systems	Floating drum biogas systems	Flexi biogas systems
Cost (US$)	1000	900–1200	410–810[a]
Retention time (days)	45–100	45–100	15
Lifetime (years)	20	10–15	15 (Greenhouse replacement every 5)
Construction time (days)	20	20–25	1
Main materials	Masonry, wood	Masonry with steel gas holder	Plastics and PVC tarpaulin bag
Portability	Fixed	Fixed	Mobile
Start up manure required (tons)	5	5	1

[a] Refers to pilot testing price, not the actual price of systems today.

Figure 1: Feature comparison of biogas systems. Source: (Sovacool, Kryman & Smith, 2014).

As of 2014, all but 3 of the 500 FBS digesters were still in operation, which is an extremely high operability rating for this type of project. Sovacool et al. (2014) noted several early failures in the pilot phase of the IFAD project as well as the following adaptations that the IFAD and Biogas International took to eliminate those failures. Additionally, it is noted that the IFAD has begun working the Indian Institute of Technology to further refine the system in preparation for deployment in India. While the IFAD biogas project has been largely successful, Sovacool also notes challenges in technical and training problems, poor policy coordination, and a low post-pilot project adoption rate in the communities. As well as the obvious poverty and financing issues, Sovacool et al. also blame the low adoption rate on a lack of widespread biogas information, limited rural water access and a negative stigmatization against biogas. The stigmatization against biogas technology is blamed on failed projects in the 1990s as well as a general skepticism for balloon technology in general due to previous failures (Sovacool, Kryman & Smith, 2014).

Other studies completed in Kenya have shown that, while present, there is only a small portion of the population that has a negative opinion of biogas. In another survey conducted in Nakuru, only 3% of the 200 farmers surveyed in the Nakuru and Nakuru

North districts who didn't own a biogas system blamed it on a negative opinion of biogas. The two most common reasons were due to a lack of knowledge and a lack of money (Mwirigi, Makenzi & Ochalo, 2009).

2.2.2 Theory

Biogas development was successful in large-scale agricultural projects in developed nations, but dissemination was not as successful for small-scale biogas plants for households in developing nations. Research from 1996 by Caceres and Chiliquinga sought determine the cause for the failure of dissemination. Caceres and Chiliquinga classify all the problems met by rural biogas development into four different groups: technical, institutional, socio-economic and financial. (Caceres & Chiliquinga, 1986).

Technical problems include operation and maintenance insufficiencies, feedstock located too far away from the biogas plants, and design/construction problems. Institutional problems include a lack of guidelines to support the technology, insufficient coordination, and a lack of national biogas programs and training programs for extension workers to learn to use the biogas technologies. The socioeconomic problems they outlined include the large upfront investment costs being too high for most rural farmers, households being resistant to change and difficulties for communities to adapt to new technologies. The financial problems included uncertainty, a lack of fair and acceptable credit policies and insufficient budgeting for research projects. While Caceres and Chiliquinga noted this in Latin America, it has also been found to be consistent with the problems faced by other regions the developing world (Caceres & Chiliquinga, 1986).

Another problem addressed by Caceres and Chiliquinga (1986) is that, during their evaluations, they observed that digesters that were financed largely by the users tended to have better maintenance and better location suitability. They noted that the most heavily subsidized biogas plants were less likely to remain operational. Ji-Qin Ni and Edmond-Jacques Nyns (1996) built off of the foundation of Caceres and Chiliquinga's work along with other relevant research papers of the time and developed an original concept, the *Biogas Producer-Consumer Combination Problem* (BPCCP). The BPCCP sought to define the factors that influence the adoption and successful operation of biogas digesters in rural areas.

Ni and Nyns (1996) analyzed the problems and facts brought up in published works and created a summary of the main characteristics of rural biogas development in developing nations. Ni and Nyns came up with a model based on the similar circumstances observed in many developing nations. This model shows the factors that act together and lead to either successful or unsuccessful biogas technology adoption (Ni and Nyns). In Figure 2, Ni and Nyns seek to combine both the external conditions and internal conditions that led to the motivation of the potential customer for adopting a new biogas system (Ni & Nyns, 1996).

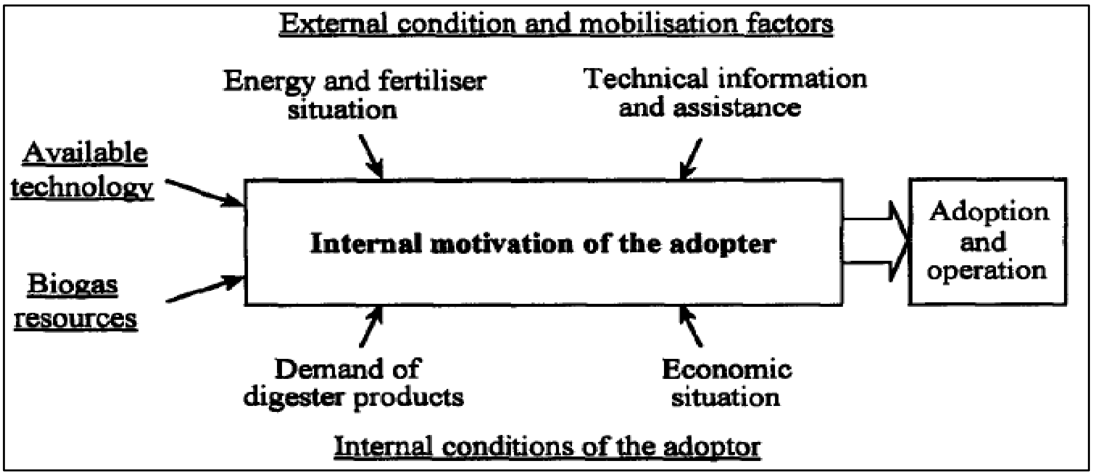

Figure 2: Factors that influence adoption and operation of rural digesters. Source: (Ni & Nyns, 1996)

The BPCCP concept looks at the combination of the costs for the biogas producer and benefits for the biogas consumer and works under the idea that individual families that adopt biogas systems are both the producers and the consumers of biogas. BPCCP theorizes that the effect on a family's income will affect both their desire to produce and their desire to consume, which makes the motivation to adopt biogas a more complex concept to understand. If a family's income increases, they will potentially have more desire to invest in biogas technology, but since they are also the biogas producer, that family must also go through the work of operating and maintaining the biogas plant, which reduces the convenience of using biogas and may negatively affect their desire for adopting it. On the other side, a family with a low income sees the economic benefits of biogas and isn't as bothered by the inconvenience, but the family has too much difficulty investing due to their low income. Ni and Nyns quantify the motivation of the consumer (Mc_1) as:

$$Mc_1 = P_1 * T_1$$

The motivation of the consumer is based on the given energy price *(P)* and the technology level *(T)*. The motivation of the producer (*Mp)* is:

$$Mp_1 = \frac{P_1 * T_1}{E_1}$$

The motivation of the producer is dependent on the *P*, *T*, as well as the family income *(E)*. Within the model, technology level is further classified as being dependent on efficiency *(e)*, investment requirement *(i)* and operation requirement *(o)*. Since the BPCCP principle looks at the combination of the consumer and the producer, the equation for the motivation of a potential adopter is as follows:

$$M = \frac{P_1 * T_1}{E_1} + P_1 * T_1$$

Based on this equation, energy price increases and technology increases can be seen to increase the desire of the producer and consumer side of the function, whereas an increase in income will only increase desire for the consumer side of the equation while decreasing the desire from the producer side of the equation. The BPCCP seeks to look at biogas development at the adapters level rather than the national level. The adapter, who is also the producer and consumer of biogas, is indispensable in the discussion of biogas dissemination. Without the potential adapters full interest, the operation and maintenance may be neglected as noted in many parts of the world through early biogas adoption failures (Ni & Nyns, 1996).

Further research, when considering biogas technology adoption, includes research published in Agricultural Economics in 1995. Adesina and Baidu-Forsen (1995), who conducted research in Guinea and Burkina Faso found strong evidence that the commonly held sociological theory of subjective perceptions also applied for farmer's perceptions on adopting new technologies. The research suggests that households are affected by subjective preferences about adopting any new technology. They concluded that farmers' subjective perceptions of new technologies should be noted when considering projects such as biogas development projects (Adesina, Baidu-Forsen, 1995). According to basic economics, the rational person will prefer the option with the higher utility. When attempting to introduce a new technology, farmers will then be comparing the utility of the new technology with that of the old technology. Farmers will only adopt a new technology if it is perceived to provide higher utility than the traditional technology (Feleke and Zegeye, 2006). Kelebe, Ayimut, Berhe & Hinsta (2017) built off the framework of previous research and investigated the factors that significantly affect biogas adoption decisions. They discovered that the factors were predominantly socio-demographic factors and access to basic infrastructure. The primary point that should be noted from the research by Kelebe et al. is that biogas promotion and projects should be tailored based on the community rather than creating a unimodal approach (Kelebe, Ayimut, Berhe & Hinsta, 2017). The socioeconomic factors that affect biogas adoption decisions will be covered more in a further section.

2.3 Biogas and the Environment

Biogas provides a relatively cleaner energy source for those households who would otherwise use wood fuel or charcoal. Because of this, biogas development is especially important in developing nations. This technology advancement will decrease the local reliance on wood fuel, charcoal, or other traditional biomass alternatives. In Kenya, biogas is especially important due to the relatively low access rates to the electricity grid. As of 2009, only 16% of Kenyans had access to the electricity grid (Roopnarain & Adeleke, 2017).

According to Okumu & Muchapondwa (2017), between 2000 and 2010, deforestation of approximately 50,000 hectares has occurred in Kenya's major water-producing Mountain ranges. Ecosystem services are especially important to consider because the value of many of these ecosystem services are difficult to evaluate and understand the exact effect on the GDP and quality of life. Measuring the value of a pristine pine grove and the benefits it provides to maintaining clean water and air are difficult to evaluate (Okumu & Muchapondwa, 2017). Deforestation additionally increases the occurrence of natural disasters which can lead to loss of life, destruction to housing and loss of crop production. Droughts, floods and landslides are all potentially increased by deforestation (Mwesigye, Buhwezi, Arineitwe & Colonna, 2011).

While it is shown that biogas digesters can reduce deforestation, the direct link between the rate of deforestation and the use of wood fuels is difficult to determine due to the collection of already fallen trees for wood fuels. A 2014 assessment looking into the potential for biogas development in Africa estimated that 70(+/-42)% of deforestation can be attributed to wood fuels. The uncertainty in the figure comes from the uncertainty surrounding the energy makeup of households who often use multiple fuels and from the uncertainty regarding the efficiency of the wood-burning stoves that are used. This efficiency varies greatly from between 14% in an open fire to 44% using a rocket stove. The assessment concluded that the deforestation attributed to wood fuel collection is expected to rise to 83(+/-50)% by 2030 (Subedi, et al., 2014). While the demand per capita for fuel wood has decreased over the years, the demand for wood fuels has been rising steadily in Africa due to increasing population size. Figure 3, taken from the Food and Agriculture Organization (FAO) shows the increasing production of both fuelwood and charcoal in Africa over the past 40 years.

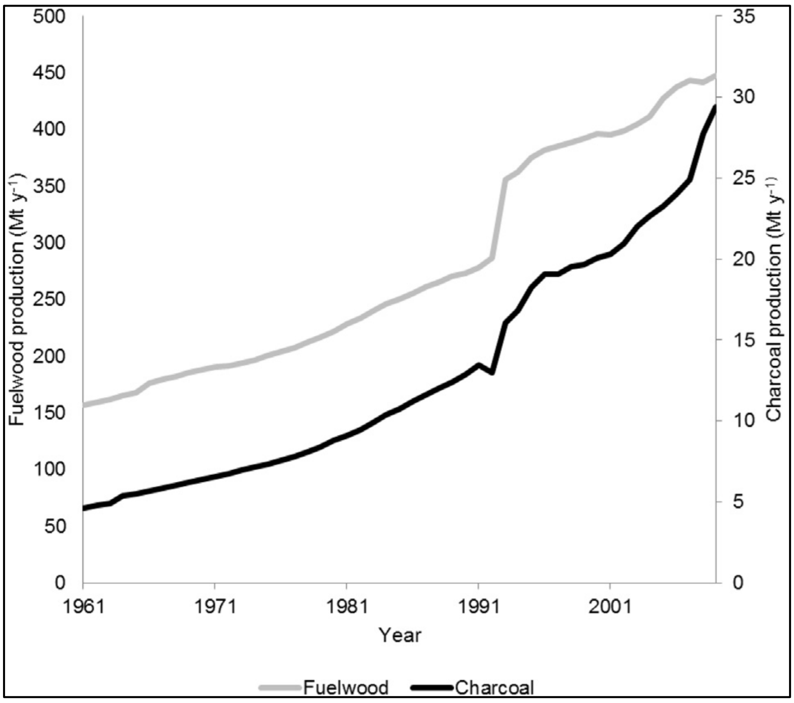

Figure 3: Fuelwood and charcoal production growth in Africa. Source: (FAO, 2011).

According to the FAO, the fuelwood production in Kenya has increased 197% from 1961 to 2009, growing from 6,259 to 18,619 kilotons. Similarly, the charcoal production has increased 925% from 1961 to 2009, growing from 88 to 902 kilotons (FAO, 2011). Returning to the data gathered by Subedi et al. (2014), biogas technology adoption in the region has the potential to decrease deforestation by 4 to 26% by 2030 through a decrease of fuelwood collection (Subedi, et al., 2014).

In addition to the potential of reducing deforestation, there is additional environmental benefit that is gained from the slurry. Using biofertilizers in place of nontreated manure leads to lower atmospheric gaseous emissions and less diffuse pollution coming from leaching and run off. Another benefit is the potential for a reduction of weed seeds that could otherwise spread unwanted weeds wherever the manure is spread (Lukehurst, Frost & Al Seadi, 2010).

2.4 Biogas and Policy

The Kenyan government has attempted to both incentivize forest management and to increase the community interaction in forest management through a concept called participatory forest management (PFM). Maintaining ecosystem services is difficult because they are frequently public goods that can be enjoyed by the local population without charge. When there is market failure in provisioning these goods, the ecosystem services will be depleted at a higher rate than the ecosystem can maintain. In Kenya, both market failures and policy failures exist as large threats to protecting forest ecosystems (Okumu & Muchapondwa, 2017).

Okuma & Muchapondwa (2017) reported that between 2000 and 2010, deforestation of approximately 50,000 hectares has occurred in Kenya’s major water-producing Mountain ranges. The cash revenue of this amounted to approximately 1,362 million Kenyan shillings (KSH) per year, whereas the costs accrued through a loss of regulating services is estimated at approximately KSH 3,652 million per year. In Kenya, forestry is based on market-based transactions while the values attributed to the individual ecosystem services for the local communities isn’t precisely known and the benefits of the ecosystem services are often not well understood in the communities. The Kenyan Government is attempting to use PFM to inform the values, attitudes, and preferences of locals to improve public knowledge about the importance of environmental services and their conservation (Okumu & Muchapondwa, 2017).

In 2010, Kenya developed the Kenyan National Domestic Biogas Programme (KENDBIP), which was initiated by the African Biogas Partnership Programme (ABPP). By the end of September 2013, this program had already led to the installation of 10,000 biogas digesters and had positively affected the lives of approximately 50,000 Kenyans (Roopnarain & Adeleke, 2017).

2.5 Biogas and Health

When examining the health benefits of biogas, what is examined is the reduction in negative health consequences from the decline in traditional biomass energy usage. Traditional biomass energy includes wood fuel, charcoal and occasionally animal dung or plant waste. Approximately 40% of the world population still use traditional biomass fuels and it is understood that these fuels have major health implications with approximately 4.3 million deaths annually attributed to household air pollution (HAP). HAP is caused by open fires and traditional cooking stoves, which produce a broad variety of pollutants that are damaging to human health, including small particles and carbon monoxide (WHO, 2012).

Often, the particulate values in the air within a home using traditional biomass fuels can be up to 20 times higher than international guidelines (WHO, 2018). Due to this statistic, it is estimated that approximately 33% of lower respiratory infections are due to smoke inhalation from cookstoves. (WHO, 2015). Similarly, exposure to cookstove smoke leads to an increased risks of cataract formation (Smith et al., 2014), high blood pressure (Baumgartner et al., 2011), and stroke (WHO, 2016).

HAP is especially abundant in Africa, with 94% of the rural African households using wood fuel as their primary energy source. In Kenya, the percentage of rural households that use traditional biomass is at 90%. According to a study published in Rural21, the leading international journal for rural development, the number of consumers of wood fuel is expected to increase from 2.5 billion in 2004 up to 2.7 billion by 2030 (Ndegwa, Breuer & Hamhaber, 2011).

While it is understood that HAP has health impacts, not very many studies have observed the connection between HAP and stillbirths and neonatal mortality. In a 2015 study completed in India, Pakistan, Kenya, Zambia and Guatemala, researchers studied 65,912 pregnancies from households that used either predominately clean fuels or predominately polluting fuels. The study, which controlled for maternal education, parity, baby gender, antenatal visits and delivery location, showed that exposure to HAP increases the risk of stillbirths and very early neonatal mortality (Patel et al., 2015). The United Nations announced in 2010 the Global Alliance for Clean Cook Stoves, which is a program that has a goal of leading 100 million homes to adopt cleaner and more efficient stoves or fuels by 2020. More research is still needed to evaluate more concretely the benefit of improved fuels to determine how many lives can be saved (United Nations Foundation, 2012).

Dohoo et al. (2013) completed a survey in the Mukurwe-ini area in central Kenya. 62 female dairy farmers were surveyed, half of which recently installed biogas plants and half of which use traditional biomass fuels. Dohoo et al. questioned women, who are understood to be the most effected by the negative factors associated with wood fuel collection and cooking. Dohoo et al. noted large differences between those women who used biogas and those who used traditional biomass reliant stoves. Only 43% of the women with biogas stoves reported any breathing problems compared to 71% from the biomass group. Women using traditional biomass also reported higher rates of shortness of breath, difficulty breathing, and chest pain while breathing during the past 6-month period (Dohoo et al., 2013).

In a 2013 study, Martin et al. recorded major research gaps that exist in understanding the health effects of traditional biomass stoves and their relationship to seven associated diseases. The researchers also noted that visible outcomes linked to early childhood survival and health are the issues that could lead to having the greatest impact leading to international action. The paper called for further research to prioritize the following health topics that are included in Table 1 on the following page.

Table 1: Summary of the major research gaps that exist involving HAP exposure. Source: (Martin et al., 2013).

Health Topic	Major Gaps and Needs Identified
Cancer	• Determine the risk from coal-related HAP exposure on cancer of organ systems other than the lung. • Assess the risk from biomass-related HAP exposure for cancer of the lung, upper airway, and other organ systems. • Investigate whether risk is mediated via germline, somatic, or epigenetic changes and whether there is a developmental window of susceptibility.
Infections	• Carry out population-based studies to determine the impact on important infectious diseases, including TB and malaria (the latter via effects of smoke on biting and disease transmission), and the impacts of interventions. • Extend the experience of the RESPIRE study on acute child pneumonia to other populations and cultures and determine etiology (pathogens) and exposure–response relationships more precisely. • Leverage existing epidemiologic studies investigating pneumonia and the impacts of new vaccines by adding HAP exposure assessment.
Cardiovascular disease	• Use short- and longer-term observational studies (including those leveraging existing cohorts) and intervention studies to determine the risk of completed cardiovascular outcomes, indicators of disease process (e.g., ECG findings), and risk (e.g., blood pressure, lipid levels, inflammatory biomarkers). • Determine the role of HAP in the developmental origins of CVD through long-term cohort studies.
Maternal, neonatal, and child health	• Strengthen existing evidence on pregnancy outcomes (pre-term birth, IUGR, stillbirth), with assessment of gestational age and vulnerable periods of exposure during pregnancy. • Investigate the risk of severe infection in neonates and young infants. • Strengthen emerging evidence on child growth and cognitive development to 5–7 years of age. • Determine the risk of HAP exposure for the main causes of maternal mortality and morbidity. • Establish long-term cohorts to study the role of early HAP exposure and associated mechanisms (including epigenetic) in the developmental origins of later childhood and adult disease.
Respiratory disease	• Use cohort studies and clinical trials to determine the roles of HAP in both causation and exacerbation of asthma in children. • Assess the impacts of HAP exposure reduction on the rate of lung function decline over the medium term (e.g., 5 years) in young/middle-aged women. • Describe the risks of HAP exposure in pregnancy and early life for lung development, asthma, and COPD.
Burns	• Enhance surveillance and population-based evidence on the causes, incidence and mortality, disability, and longer-term social impacts of burn injuries. • Assess the impact of safety testing of new stoves. • Determine the value of prevention strategies on morbidity and mortality related to burn injuries or accidental poisoning (e.g., with kerosene) from cooking, heating, and lighting.
Ocular disorders	• Extend the evidence on cataracts in men and in exposed populations outside of India. • Ensure better control of potentially serious confounding in studies of cataract (e.g., smoking, UV light exposure, nutrition). • Strengthen tentative evidence on risk for other important ocular disorders, such as trachoma. • Investigate the motivational potential of reduced eye symptoms (tearing, irritation) for intervention programs.

2.6 Biogas and Gender

In most African households, men and women have different roles, with the energy provisioning burden often falling on the woman. Because women are the main energy provisioner, they also bear the health risks associated with their energy usage. Women are thus affected proportionately more by HAP when higher polluting energy sources are used. In energy poor nations, the rural poor often have no decision about the type of energy they use in their daily lives, and thus women will be disproportionally disadvantaged without opportunity to improve their health by switching energy sources. (Muchiri, 2008).

The Kenyan government is working to eliminate such issues and has signed several international conventions and treaties, including the Convention on the Elimination of all Forms of Discrimination against Women (CEDAW), the Commission on the Status of Women, and the African Platform of Action. Unfortunately, these agreements often have no binding commitments or mechanism for tracking gender equity or simply require periodic reporting (Republic of Kenya, 2004). It should be noted that since the 1992 United Nations Conference on Environment and Development (UNCED), there has been an international consensus to assure that development both drives forward economic growth while defending the social equity and the environment. (Muchiri, 2008).

Energy policy is often gender-blind whereas the energy situation that occurs within households tends to disadvantage women, because of this, gender-blind energy policy will make it harder to achieve the sustainable development goals (SDG) that are put forward by the United Nations Development Programme (UNDP). Research and projects have been started by the Gender and Energy Research Programme (GERP), which is attempting to reform energy policies in a gender-sensitive way. The goal of GERP is to strive for both women empowerment and poverty reduction, which are goals of both the SDG and the UNDP (Clancy & Stockbridge, 2017).

In a 2014 domestic biogas survey commissioned by KENDBIP, 240 households were surveyed to determine the effectiveness of biogas plants throughout Kenya. This survey showed gender bias when it comes to fuel collection. Women were 22% more likely to be involved in fuel collection, likely due to women being more often tasked with kitchen work. When the fuel used by the household was firewood, the statistics were almost equal, with 90% of adult men collecting fuel wood and 92% of adult women collecting fuel wood. However, the bias was much more apparent with children. 53% of girls collect fuel wood compared to 28% of boys. The conclusion reached was that adult male activity tended to involve chopping down larger trees for more long-term fuel supply. The surveyors also estimate that biogas installation can save up to three hours a day for rural women through a reduction of fire wood collection, washing and cook time (Nyamu, 2014).

In the previous section, a survey by Dohoo et al. was introduced. While the survey took samples from only women and was focused on health rather than gender disparity, the information is important to be included here as well due to the burden women have due to energy provisioning. They are the predominant kitchen workers and installing a biogas plant has great effects on the amount of time it takes to cook with traditional biomass. In the survey it was noted that women who have installed biogas plants spend approximately 509 minutes per week exposed to woodhouse smoke compared to 1,122 minutes per week for those women who use traditional biomass (Dohoo et al., 2013).

2.7 Biogas and Socioeconomics

Socioeconomics play a large role in the adoption of biogas, and similarly the adoption of biogas can play a large role in the ability of a household to improve their socioeconomic situation. Sovacool et al. (2014) notes that biogas systems are a solution that can help solve three of the major problems that Kenya is facing; climate change vulnerability, declining food security and unequitable energy access. Biogas technologies can mitigate greenhouse gas emissions, improve agricultural sustainability, and reduce energy poverty (Sovacool, 2014). While Sovacool focuses on the benefits of biogas, later research from Kelebe et al. (2017) looks at the factors that affect a household's desire to adopt biogas. The survey discovered that most of the determining factors were socio-demographic factors such as family size and education level, as well as access to infrastructure. Table 2 is adapted from the research done by Kelebe et al. (2017) and shows the socio-demographic factors that have the greatest effect of biogas adoption decisions on households.

Table 2: Factors that effect a household's biogas adoption decision. Source: Adapted from (Kelebe et al., 2017).

Positive	Negative
Age of household head	Distance to the nearest market
Family size	
Level of education	
Cattle size owned	
Distance to firewood collection site	
Access to electricity	
Access to credit	
Access to all weather roads	
Female headed household	

Similarly, Mwirigi et al. (2009) noted that the education level and the occupation of the head of household often had a major impact on the household's decision about whether to adopt biogas technologies, with those with higher education levels being more willing to adapt to new ideas and technologies (Mwirigi et al., 2009). While Biogas adoption is more readily available to those of higher economic status, when it is adopted it has the potential to increase one's socioeconomic status. Households who manage to purchase and install biogas plants can focus more time and money on alternative activities, such as education, business or improving their quality of life (Sovacool, et al. 2014).

Biogas International is working within Kenya to enhance the market approach of biogas companies to provide an outlet for entrepreneurs to make more money off their biogas plants. The organization is trying to expand their compressed natural gas plant to allow packing biogas into canisters, which would enable the FBS byproduct to be used as an income enhancer rather than just a financial loss mitigator. Figure 4 shows the model that Biogas International is trying to use to better incentivize the growth of business opportunities using biogas technologies. The model provides a good example of how someone could benefit from the FBS system through entrepreneurial activity. The model also acts as a general statement example of the opportunities that adopting biogas can give to a household to help them improve their socioeconomic standing (Sovacool et al., 2014).

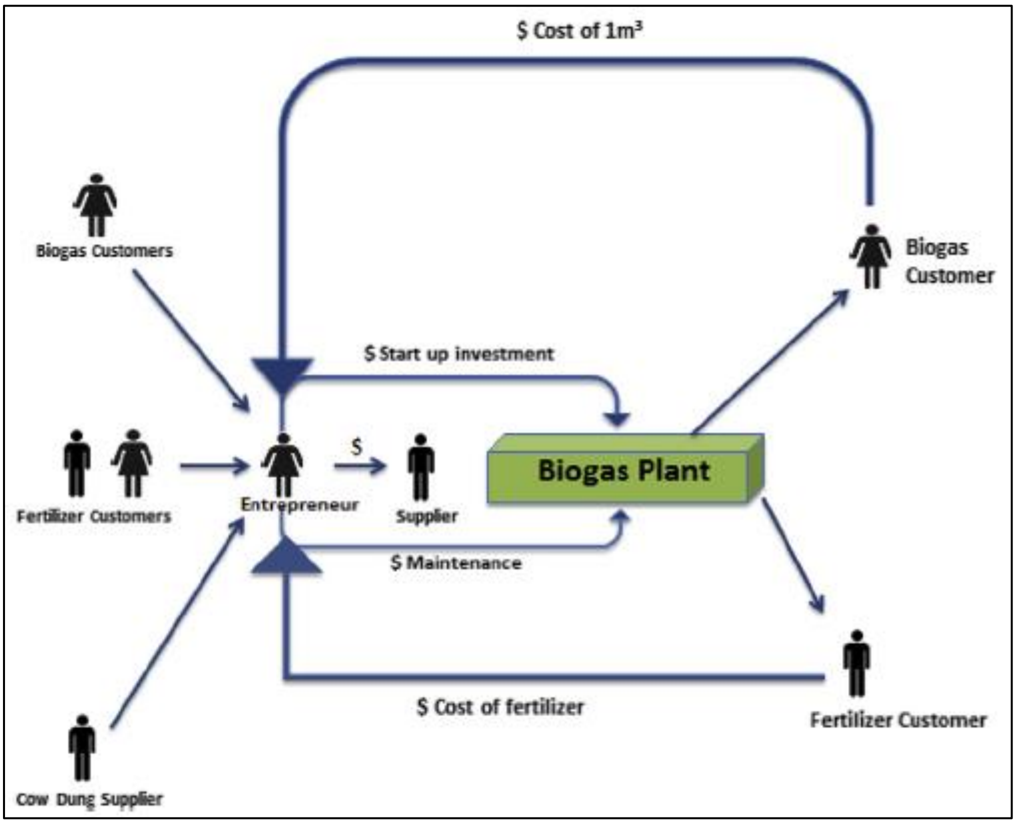

Figure 4: Model for biogas distribution in urban areas. Source: (Sovacool et al., 2014).

2.8 Challenges to Biogas Acceptance

A large percentage of the population in Sub-Saharan Africa rely on traditional biomass. The region can benefit greatly from biogas, but despite this, adoption is occurring at a very sluggish pace in the region. According to Mulinda et al. (2013) the largest factors that have led to the slow adoption rate of biogas in Africa include the following points, which will each be discussed in a little more detail along with other relevant research (Mulinda, Hu & Pan, 2013).

1. Availability of inputs,
2. High initial investment cost,
3. Lack of information sharing,
4. Political and security issues,
5. Pilot plant project failures

2.8.1 Availability of Inputs

Household biogas digesters in Africa are usually fed daily with cow manure. For a biogas digester to be successful, it needs to be able to support a family. African families tend to be relatively large and consequently big digesters are required. While the family sizes in Africa are declining, they are still quite high. When considering Kenya, as of 2014, the average family size was 4.0 people per household compared to the average of 2.0 people per household in Germany (United Nations, 2017). The larger the size of the digester, the more inputs the family will need. Inputs include fresh manure and water, both of which require labor (Mulinda et al., 2013). Recalling the previous work from Ni and Nyns that considered the family to be both the producer and the consumer, an increasing family size leads to an increase in the input costs and thus can lead to less desire for biogas technology adoption (Ni & Nyns, 1996).

2.8.2 High Initial Investment Cost

While biogas plants have no monthly cost for energy production, they do have a relatively high initial investment cost as well as labor required for operation and maintenance of the plant, for storage, and for slurry usage or disposal. Failure to maintain a biogas plant can lead to complete failure of the biogas system and a loss of the initial investment. The major bottleneck in the adoption of biogas plants in Africa is the initial investment due to the large amount of people on the continent living below the poverty line (Mulinda et al., 2013).

2.8.3 Lack of Information Sharing

According to Mulinda et al., as of 2013 there was a relative lack of information sharing as well as a lack of recent biogas technology research in Africa. While there is plenty of research on biogas technology available, localized information about biogas projects, successes and failures, and project information is lacking. While the possibility for technology transfer is high, the barriers have led to relatively low transfer and thus local entrepreneurs have been slow to take advantage of the opportunities and develop solid business plans (Mulinda et al., 2013). As noted previously, KENDBIP and Biogas International are attempting to increase the information sharing and improve the infrastructure for biogas growth and information sharing within Kenya (Sovacool et al., 2014).

2.8.4 Political and Security Issues

Periods of food insecurity and financial or political instability often overshadow the possibilities of locals to get involved in economic development projects (Mulinda et al., 2013). Both fixed-dome and floating-drum style biogas plants are relatively permanent installations that require land security and access to some consistent level of infrastructure to assure proper maintenance and functionality. Mwirigi et al. (2009) found results that showed the statistical significance with a landowner owning a title deed and their willingness to adapt biogas technology. Land security gives the adopter more assurance that their investment will receive the expected return. (Mwirigi et al., 2009).

2.8.5 Pilot Plant Project Failures

The final point argued by Mulinda et al. is that the earliest biogas projects that occurred more than four decades ago led to many failures which negatively affected people's opinion about biogas technology. Most digesters constructed during this period failed due to various reasons. The technology requires skills to maintain and operate, as well as social acceptance (Mulinda et al., 2013). One problem leading to pilot project failures is that many of the subsidized projects occurred in locations that are less than ideal or have operators who aren't very invested in the biogas plant. Sun et al. (2014)

calculated that in China, a 10% increase in the subsidy-cost ratio only led to a 1.15% increase in biogas use due to the increased project failures (Sun et al., 2014). Biogas plants that have been paid mostly by the producer and consumer lead to a higher success rate, and those that are more highly subsidized have a higher failure rate. For the highest biogas success rate, the user should pay most of the costs and the subsidies should just be available to support the poorest users. Additionally, innovative financial systems such as microfinance and after-sale maintenance subsidies should be considered (Garfi et al., 2016).

3 Taita Taveta Regional

3.1 Biogas in Taita Taveta

According to a 2007 assessment assessing the potential and benefit of biogas development in Africa, Kenya has a technical potential of 1.25 million households that can support biogas, which is based on the availability of dung and water (Heegde & Sonder, 2007). If other inputs are considered for digestion, the potential could be much higher. In 2007, a feasibility study was conducted throughout Kenya to promote biogas systems. This identified at least 35 districts that have large technical potential for biogas development, and recommended a further focus on five primary districts, Kakamega, Kiambu, Kisii, Nakuru, and Nyandarua. The survey emphasized the benefits of zero grazing units on the success of pilot projects (Adoyo et al., 2007). The primary biogas plants that are installed in Kenya are the floating drum and fixed-dome digesters, which generally require the manure of 2 cows for reliable biogas production. Recently, the plastic tube digester, which is much cheaper, has also seen increased usage (Roopnarain & Adeleke, 2017). Newer biogas technologies such as the plastic tube digester (Sovacool et al., 2014) and the Smart Biogas Plant by Nagaro (Khan, 2017) can provide biogas with fewer manure inputs.

While Taita Taveta County was not mentioned in the 2007 feasibility study, biogas adoption has been growing recently, with most of the growth being due to Biogas Taita, a local company that has trained more than 70 worksmen and installed more than 350 fixed dome biogas plants locally. The recently trained worksmen and supervisors have the knowledge to continue to install and maintain biogas plants on their own as entrepreneurs (Biogas Taita, 2018). In Taita Taveta, biogas plant installation occurred at a much higher rate between mid-2009 and mid-2013 due to biogas subsidies that were given to farmers. Table 3 shows the value of the subsidies that were given during this time (Porras, Vorley & Amrein, 2015).

Table 3: Subsidies for biodigester installation. Source: (Porras, et al., 2015)

Cost of Biodigester to Farmer		*KSH 75,000 to 100,000*	*Euros 670-890*	*% of Total Installation Costs*
Farmer Subsidy	Mid-2009 to Mid-2013	25,000	223.20	29%
	June 2013 to Mid-2013	18,000	160.70	21%
	2014 Onward	0	0	0

3.2 Regional Information

Taita Taveta County is one of the six counties in the Coastal region of Kenya and lies approximately 200 km to the northwest of Mombasa and approximately 360 km to the southeast of Nairobi. Taita Taveta County can be seen in Figure 5.

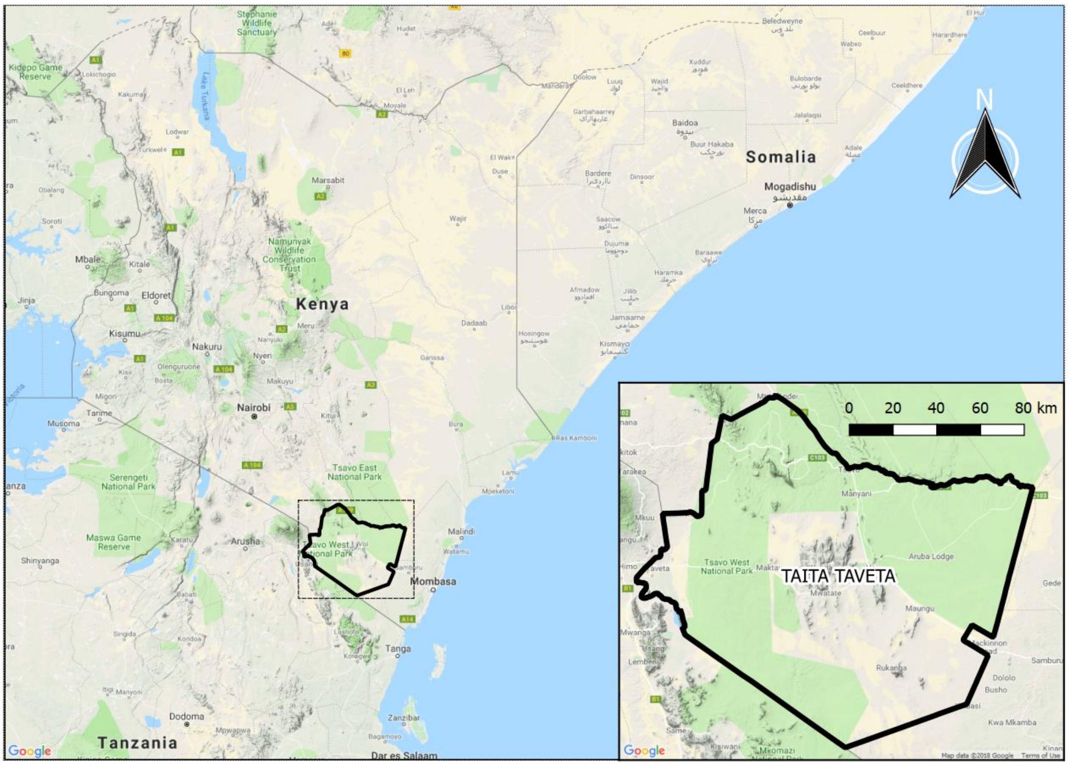

Figure 5: The location of Taita Taveta within Kenya. Source: Own illustration generated using QGIS

Taita Taveta County covers an area of 17,084.1 km^2 and consists of three major topographical zones, the upper zone, the lower zone and the volcanic foothills. The upper zone consists of mostly horticultural farming and has an altitude between 304 and 2,208 meters above sea level. The lower zone is made up of plains and has mostly ranching, national parks and mining. The last topographic zone is made up of the volcanic foothills at the base of Mt. Kilimanjaro which are relatively low in elevation and provide a large volume of water to the region through the rivers, lakes and underground springs that originate there. The entire county is supplied with water from several local rivers and springs coming from the Chyulu and Taita Hills, as well as the lakes that are fed through underground springs emanating from Mt. Kilimanjaro.

The average temperature in Taita Taveta County is 23ºC, with much lower temperatures occurring in the highlands and much higher temperatures in the lowlands. The annual mean rainfall in Taita Taveta is 650 mm, which is distributed mostly in the highlands. The lowlands have a much lower volume of rain during both the long rains from March to May and the short rains from October to December. The local community relies on the rainfall to sustain the small-scale farms which provide a living for most of the residents. In the past, agricultural farmers would frequently migrate between the lowlands and highlands depending on the season and climatic conditions, but due to recent population growth and changes in the local climate, this is no longer possible (TTCG 2013).

Approximately 62% of the Counties total area is made up of Tsavo West and Tsavo East National Parks, which consist of savannah and bush woodlands with a very high wildlife density. These ecosystems support lions, elephants, antelopes, giraffes, zebras, rhinos, hippos, crocodiles and a wide variety of other wildlife. The remaining 38% of the county is subdivided into four sub-counties and then further into twenty total wards, which is presented in chapter 4, Table 5 (TTCG, 2013).

3.3 Demographics

The most recent census occurred in 2009, where the population was recorded at 284,657 residents. 2017 projections by the county government puts the present estimated population at 345,800 residents. The human sex ratio is 1.04, with the ratio decreasing as the population ages, which indicates that men tend to have a higher death rate than women in Taita Taveta County.

Educational access, as of 2010, shows a recorded transition rate from primary to secondary institutions at 67.5%. The most common reason for students not to transfer is the lack of available spaces in public schools and the lack of income sufficient to send their children to boarding facilities that are further away. The Taita Taveta County government (TTCG) recently completed the first Taita Taveta County Integrated Development Plan (CIDP), which is an excellent source of local demographic knowledge. Table 4 on the following page includes relevant demographic statistics that have been gathered from the CIDP (TTCG, 2013).

Table 4: Taita Taveta demographic statistics. Source: (adapted from TTCG, 2013).

Demographic Statistics from 2013-2018 CIDP		
	Mobile Phone Penetration	41%
	Electricity Access	7.7%
Primary Cooking Fuel	Firewood	75.2%
	Charcoal	14%
Mean Holding Size	Highlands	0.4 Ha
	Midlands	1.3 Ha
	Lowlands	4.8 Ha
	Title Deed Ownership	35%
	Unemployment Rate	45%
	Access to Piped Water	35%
	Access to portable water	58%
	Literacy Rate	80%
	Urban Population	25.50%

3.4 Economic Activities

The primary economic activities in Taita Taveta County by inhabitants are small-scale horticulture farming and livestock rearing. In addition, large-scale sisal farming, ranching, fishing, forestry, and mining are all practiced to harvest the local resources. Small to medium businesses also exist, with an estimated 7,890 people employed in rural self-employment and an estimated 3,810 people employed in urban self-employment. Various industries, such as sisal production and dairy milk cooling plants, also employ a small amount of the labor force. Finally, tourism makes up a large part of the local economy, with the Tsavo National parks being one of the more popular tourist destinations in Kenya (TTCG, 2013).

4 Research Methodology

4.1 Introduction

In this section, the methodology and procedures that were followed during the research are presented. The goal of this section is to introduce the research and try to provide verifiability and credibility to the data as well as expose the potential limitations that exist within the data set.

4.2 Research Objective

The primary objective of the research was to determine the knowledge, capacity and desire for rural small-scale farmers in Taita Taveta County to adapt biogas technology. To reach this objective, questions were designed that explored the socio-demographic background, capacity and more general knowledge of the respondents. Additionally, the economic, horticulture, and livestock rearing activities of the respondents were collected.

4.3 Research Design

According to the University of Southern California, the research design refers to "the overall strategy that you choose to integrate the different components of the study into a coherent and logical way" (University of Southern California, 2018). It ensures that the research problem can be effectively addressed and stated as unambiguously and logically as possible. The research design works as the blueprint for data collection, data measurement and data analysis. (De Vaus, 2006). The conducted research consisted of exploratory research using both qualitative and quantitative methods. The qualitative research employed in the questionnaire seeks to understand potential decisions and opinions of the respondents whereas the quantitative research focuses on finding relationships between several variables.

4.3.1 Methods of Data Collection

All data presented in the results section (Chapter 5) are the result of primary data collected from August to November 2018. This data was collected through a questionnaire that was conducted through in-person interviews in either English, Taita, or Kiswahili, depending on the preference of the respondent. All questionnaires were delivered with the assistance of a staff member of the local Taita Taveta University. The local assistant, Mr. Wilmot Mwatela, understood all three languages used in the investigation as well as the customs and expectations of the locals in Taita Taveta. Following the presented primary data in the results section, secondary data gathered through literature review will be presented and compared with the results of the primary data for discussion and analysis in Chapter 6.

4.3.2 Target Population

The target population refers to the subset of people that fit within the sample criteria of the study (Lavrakas, 2008). The target population for this study is all rural households in Taita Taveta. Using population projections from the 2009 census, it was determined that there was approximately 308,000 people living in rural households in Taita Taveta. To successfully target all rural households, the County map was subdivided into the 20 wards and the stratified systematic sampling technique was used in combination with the sampling tool in QGIS to determine how many households to survey from each ward. 200 households were sampled out of a target population of 308,000 people. A larger sample size would be ideal, but time and monetary restraints necessitated the smaller sample size. Summary table 5 shows a breakdown of the number of samples that were taken from each ward within Taita Taveta.

Table 5: Sampling data for each of the 20 wards in Taita Taveta. Source: Population figures estimated using (TTCG, 2013).

Subcounty	*Ward*	*Rural Population*	*Sample Number*
Wundanyi	Wundanyi / Mbale	17554	14
	Werugha	8676	**7**
	Wumingu / Kishushe	14355	11
	Mwanda / Mgange	13322	10
Mwatate	Rong'e	10805	9
	Mwatate	11747	9
	Bura	20496	16
	Chawia	14077	11
	Wusi/Kishamba	13282	11
Taveta	Chala	18065	14
	Mahoo	8299	7
	Bomani	6985	5
	Mboghoni	16251	13
	Mata	9271	7
Voi	Mbololo	17415	14
	Ngolia	7875	6
	Sagala	10816	**9**
	Kaloleni	11842	9
	Marungu	9017	7
	Kasigau	13686	11

While Taita Taveta County has a very large land mass, the population of the inhabitants is mostly distributed into a few small regions. Even the rural population is very condensed, with large areas of the map having no households at all. These population-barren areas, such as the Tsavo national parks, the large-scale sisal farms, the ranches or the other regions without households visible from satellite imagery, were not incorporated into the study area. Figure 6 provides a map of the study region and shows the distribution of the sample points within each of the wards.

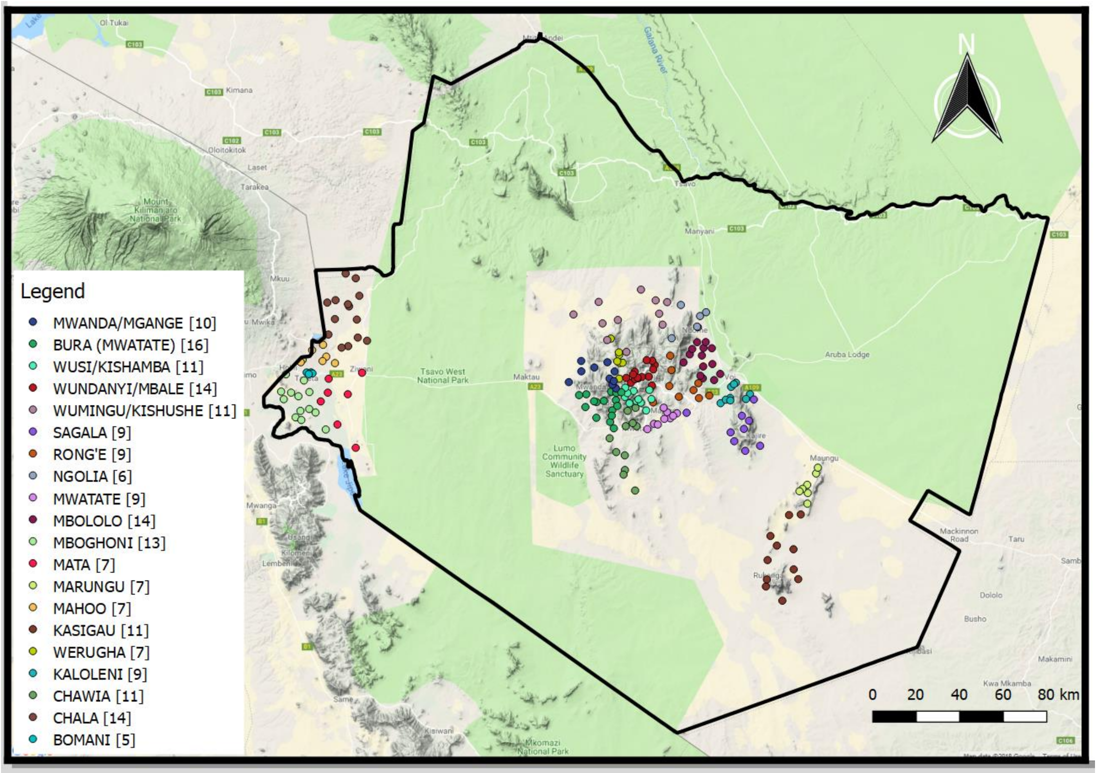

Figure 6: Sample points in Taita Taveta. Source: Own illustration. Generated using QGIS

4.3.3 Survey Design

The survey consisted of 34 questions that covered the following categories; land usage, energy usage, opinions, biogas knowledge, biogas potential, and personal information. These categories were targeted to give a better understanding of the demographics while answering the previously listed research questions. The survey is available at the end of the paper at Appendix I.1.

4.3.3.1 Land Usage

The first three questions of the survey pertain to the amount of land the farmer has available to use and what type of horticulture and livestock rearing activities that they participate in. In addition to these three questions, one of the personal questions in the survey asks about land ownership. Within Taita Taveta, many farmers live on land without a deed and this is statistically significant for willingness to adapt to biogas according to the literature review.

4.3.3.2 Energy Usage

Energy usage is directly related to the adoption of biogas technology. Four questions focus on what types of energy each household has access to and uses as well as the costs associated with each energy source. The final question in this section considers firewood and the households firewood collection habits.

4.3.3.3 Opinions

The next five questions are opinion questions that are meant to determine the respondent's awareness of commonly researched issues regarding firewood collection and biomass cooking stoves.

4.3.3.4 Biogas Knowledge and Potential

The next 12 questions consider the biogas potential of each individual household. This section considers their knowledge, capacity, savings potential, interest and desire in learning more about or potentially adopting biogas plants.

4.3.3.5 Personal Information

The last category includes 10 personal questions to contextualize the demographics and try and determine any significant findings. In this final section, in addition to basic household demographic information. The last two questions of the questionnaire ask about the respondent's community involvement and provides the respondent with the opportunity to provide any personal comments.

4.4 Limitations

The whole study went according to plan, with 200 households answering the questionnaire. Nevertheless, a sample size of 200 out of a sample population of 308,000 is too low. Due to the lower sample size, these results are only indicative results rather than truly representative of the whole population of Taita Taveta County. Therefore, the data received has a 95% confidence level with a 7% margin of error. Several questions, such as the questions referring to daily organic waste and firewood collection time are difficult for the respondent to answer accurately and may not be truly representative. The data provided should be used as indicative data to inspire further increasingly specific research in the area.

Two additional questions should have been asked to provide a stronger data set. The first question should have determined the households access to water and a second question should have questioned how many hours a week the respondent spends cooking. This information is instead taken from regional data sources and discussed as such.

4.5 Ethical Considerations

When conducting interviews, it is important to be sure that the respondent does not feel pressured to answer through any means. To assure that respondents understood the purpose of the questionnaire, Mr. Mwatela and I introduced ourselves and presented the respondents with the cover page of the questionnaire while explaining who we are and what the purpose and scope of the interview are. The respondents were assured confidentiality and informed that providing their personal information was not a requirement for partaking in the questionnaire. The respondents were also informed that if they did decide to begin the questionnaire, they could withdraw at any time.

4.6 Validity and Reliability

While the questionnaire was delivered as a standalone survey without the potential for financial gain or any other aid to the respondents, there is always a risk that some of the respondents were answering questions in a way based on their hope that certain answers may lead to increased likelihood of them receiving some sort of aid or subsidy. In a recent study in Kenya, the authors noted similarly that respondents may answer in ways that they believe gives them the most likelihood of some potential benefit, regardless of whether that potential benefit exists (Adoyo, et al., 2007).

The questionnaires were always administered through in-person interviews with a consistent translator who could interpret the questions into all three potential languages. There is still possibility that some of the questions were misunderstood or perceived differently by different respondents. This is especially relevant because the questions were administered to a target population with a very broad demographic range from illiterate to college graduates.

5 Results

5.1 Introduction

The summary of the questionnaire findings is presented in this chapter. Chapter 5 is subdivided into the following sections; Sociodemographic results, biogas knowledge, energy usage and biogas capacity. The results will be simply presented here, with chapter 6 focusing on a discussion and analysis of the data compared with the knowledge base from the literature review.

5.2 Sociodemographic Results

Sociodemographic data includes the age, gender, education level, profession, income, plot size, livestock ownership, horticultural activity and the community associations that the respondent is a part of.

5.2.1 Age and Gender

In the questionnaire, the age data is split up into age groups. As a rule, we only interviewed those that were 15 years or older. The youngest respondents were much more likely to be female, with 50 out of the 71 respondents between the ages of 15 and 35 being female. The most common age group was between 46 to 55 years old, of which there were 40 respondents. 26 respondents were between the ages of 56 and 65 and 24 respondents were 66 years or older. Only one respondent abstained from providing their age. Out of the respondents, 113 were female and 87 of them were male. Figure 7 shows a breakdown of the age and gender of all the respondents.

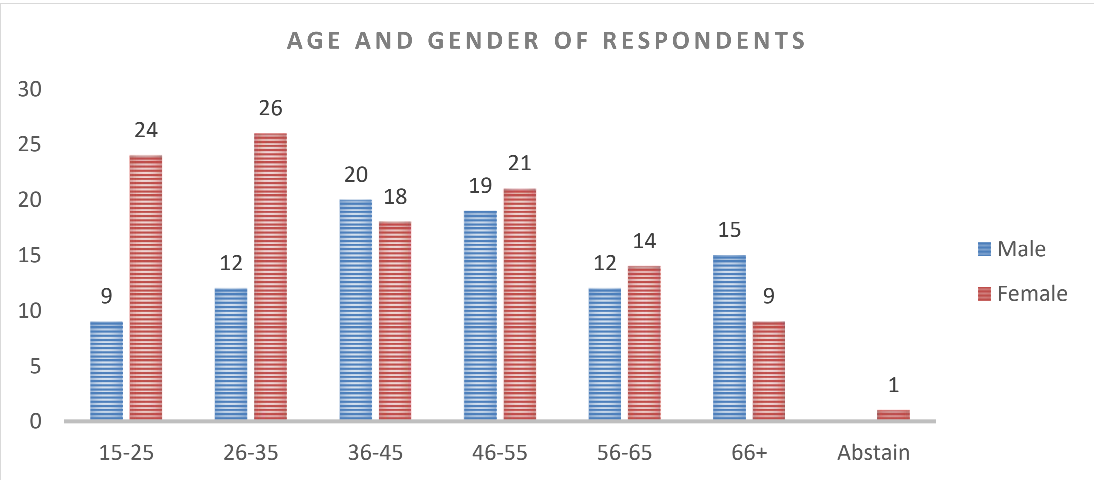

Figure 7: Source: Own illustration

5.2.2 Education Level

Out of the 200 households, 16 respondents were illiterate and had never attended schooling before. The most common education level was primary education, with 96 of the respondents having completed it. Figure 8 presents the education levels of all the respondents.

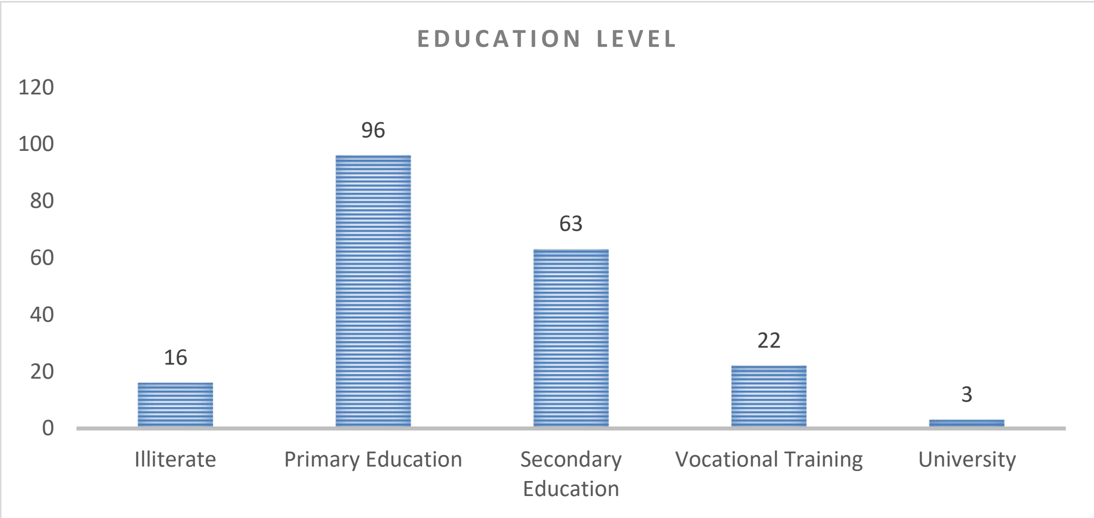

Figure 8: Source: Own illustration

Figures 9 and 10 examine the relationship between age and education and gender and education. Figure 9 on the following page shows education level relative to the age of the respondent. Of the youngest respondents from 15 to 25, there were no illiterate respondents while approximately 25% of them had only completed primary education. At all age groups, primary and secondary education were the most common response, with exception to those respondents from 56+ whose most common responses were illiterate and primary education. Secondary education was more common at younger ages. Vocational training was relatively dispersed throughout the age groups. While university was most common from 15 to 25 years old, not enough respondents studied at university to draw any conclusions from it.

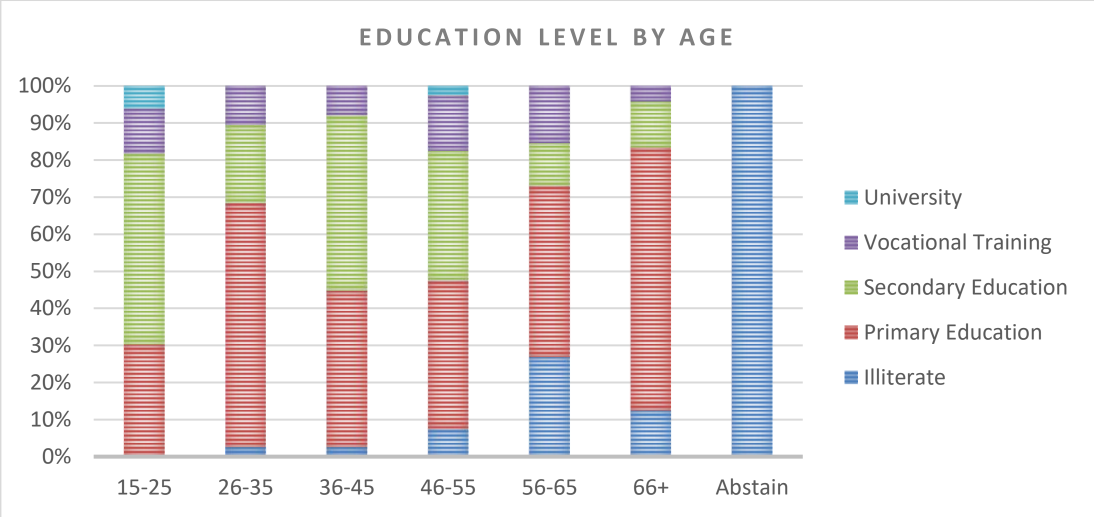

Figure 9: Source: Own illustration

The education level is also compared by genders. As a percentage, women are more represented in the lower literacy ranges with approximately 60% of the illiterate being women whereas only 43% of those who had received secondary education were women. This was further seen in the vocational training level, with only 40% of the vocational training being received by women. In university, this trend is not seen, but the university level has too few respondents to draw any conclusion from it. This data is presented in figure 10, which shows the percentage of both genders at each education level.

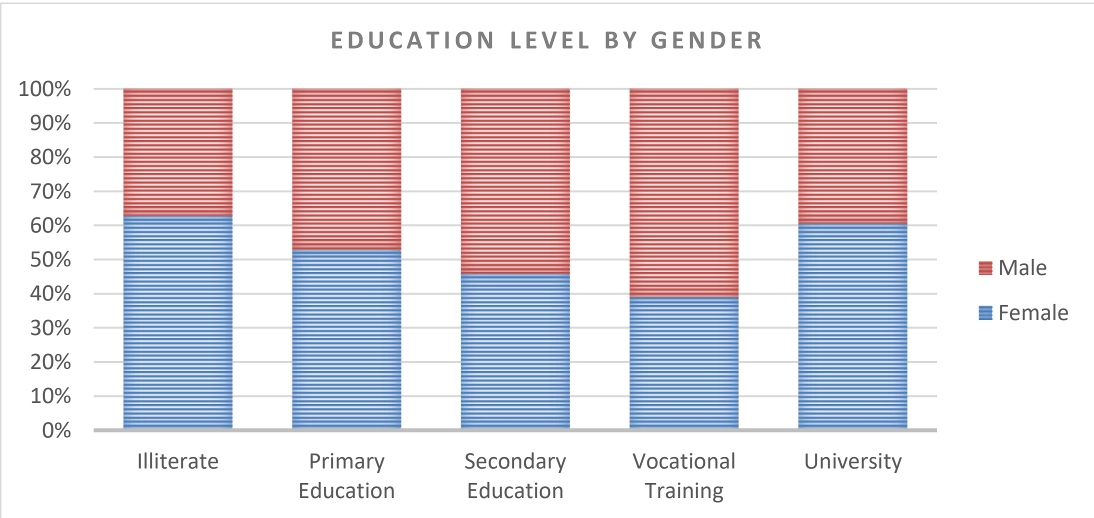

Figure 10: Source: Own illustration

5.2.3 Income

Figure 11 shows the income level of the respondents. Out of the 200 respondents, 188 offered their income. 4 respondents stated that their income was less than KSH 100 monthly while 8 respondents said that their income was between KSH 100 and 499. 21 respondents had an income between KSH 500 and 1,499 monthly. The largest percentage of the respondents had incomes between KSH 1,500 and 4,999 monthly and between KSH 5,000 to 19,999 monthly, at 60 and 69 respectively. 26 respondents had an income of greater than KSH 20,000 monthly.

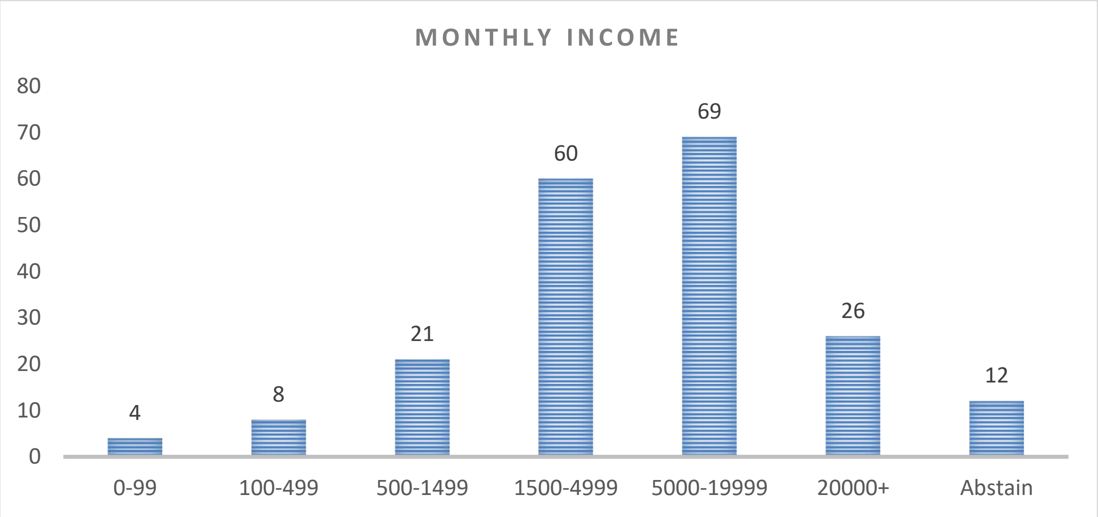

Figure 11:Source: Own illustration

Monthly income was also subdivided by education level to look for significance. The data shows that those with a higher education level are much more likely to have a higher income. In only one household did a respondent with a secondary education or higher claim to be in the bottom two income brackets. Respondents with a secondary education were much more likely to be at the highest two income brackets. Figure 12 on the following page presents the data by subdividing the household incomes according to the highest education level obtained.

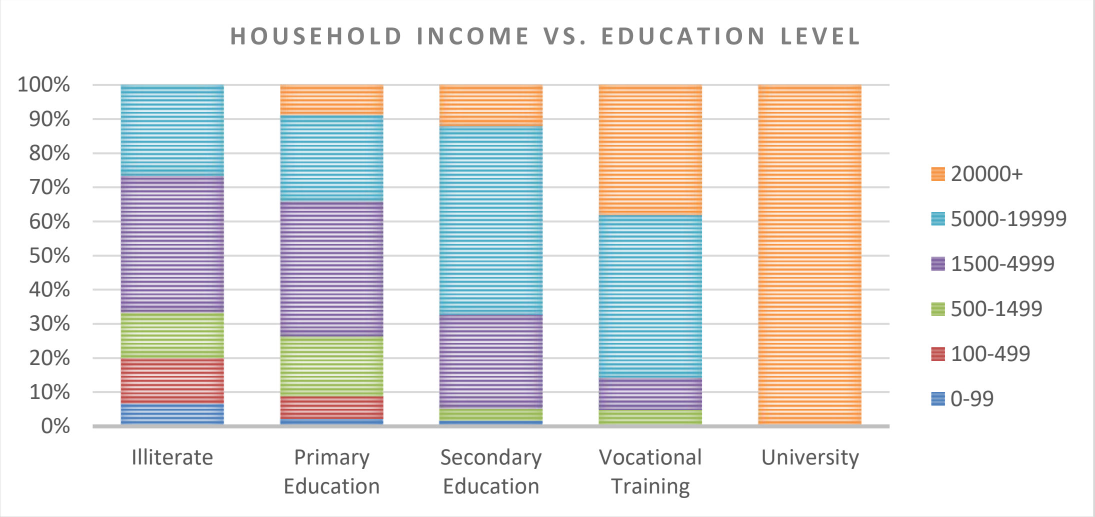

Figure 12: Source: Own illustration

5.2.4 Savings Potential

195 respondents answered the question relating to their savings and their ability to potentially save for a biogas plant. The most common response was that they could save between KSH 200 to KSH 499 every month. Figure 13 shows the distribution of the savings potential for the 195 respondents.

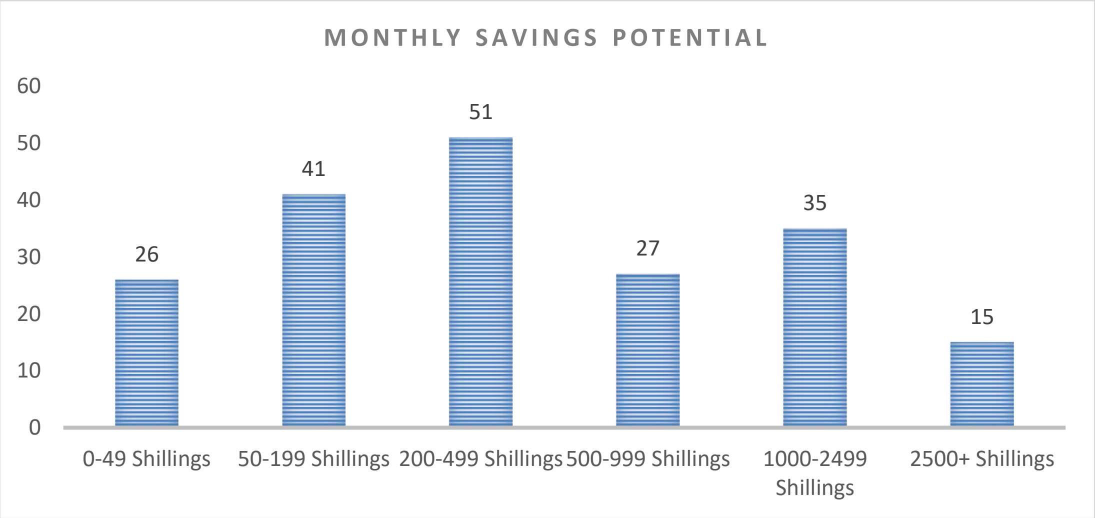

Figure 13: Source: Own illustration

5.2.5 Land

Out of the 200 respondents, the most common response to plot size was 86 respondents living on a plot smaller than half a hectare. 40 respondents lived on a plot between half and one hectare. 58 respondents lived on a plot size between one and five hectares and 14 lived on a plot size between five and ten hectares. Only two respondents lived on a plot larger than ten hectares. Figure 14 shows a distribution of the plot sizes of the respondents.

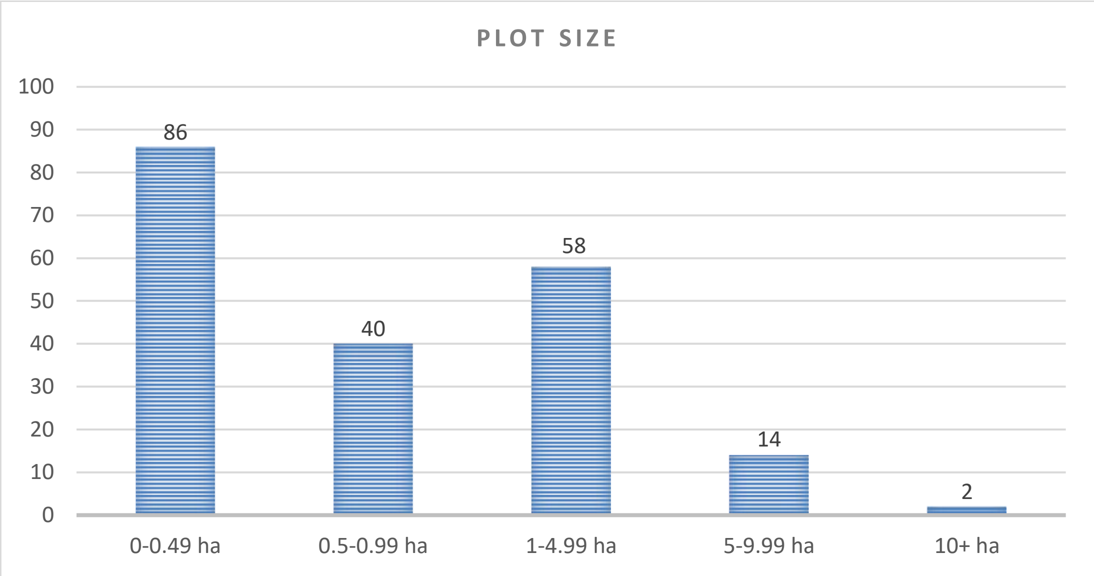

Figure 14: Source: Own illustration

Figures 15 and 16 on the following page are maps generated from QGIS that show the spatial differences in the distribution of plot size and title deed ownership in Taita Taveta County. While it is not entirely consistent, plots that are in the highlands and cloud forest regions were more likely to be below a hectare while those in the lowlands were more likely to be above a hectare. Figure 15 on the following page highlights an area around the Taita Hills where the plot size differentiation is visible. The respondents in the highlands of the Taita hills had less than half a hectare much more frequently than those in the foothills or lowlands.

Out of the 200 respondents, 122 had a title deed and 78 had not yet received a title deed. Title deed distribution was regionally significant. Several wards, such as Wumingu/Kishushe, Ngolia and Kasigau had very few respondents that had received title deeds while others like Chala, Mwatate and Mbololo had most or all respondents already owning a title deed. Figure 16 shows the region surrounding the Taita Hills and the distribution of the respondent’s location and title deed ownership.

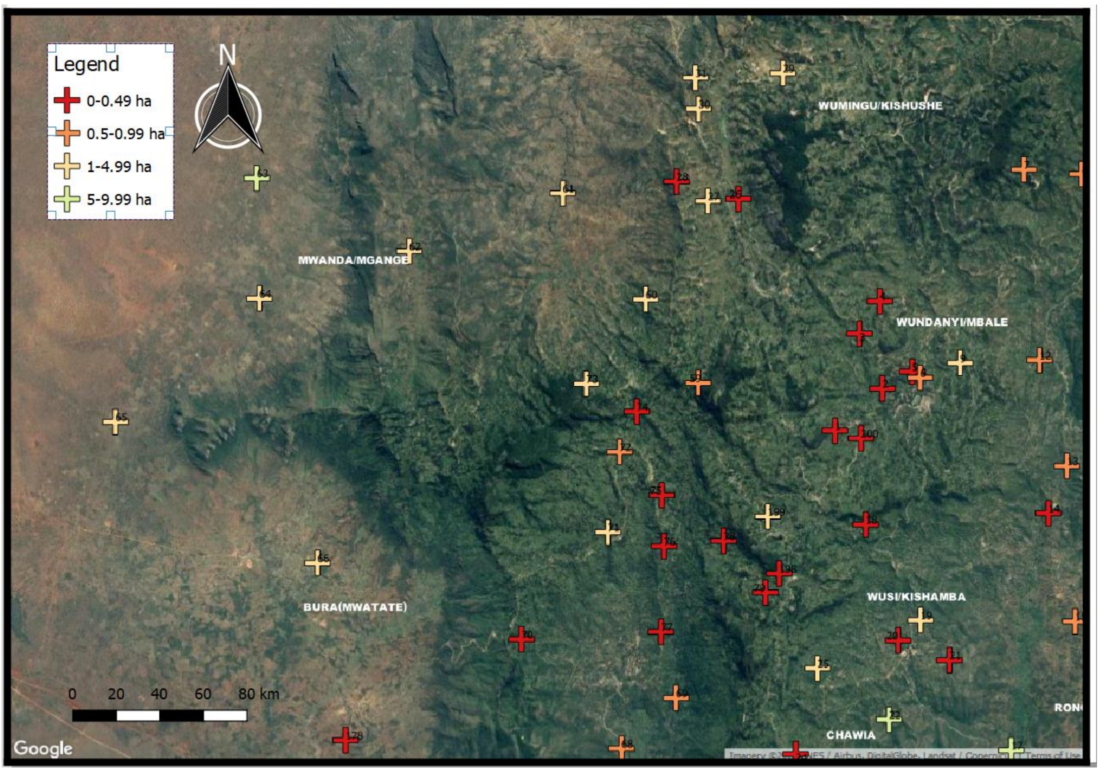

Figure 15: Plot size ownership. Source: Own illustration. Generated using QGIS

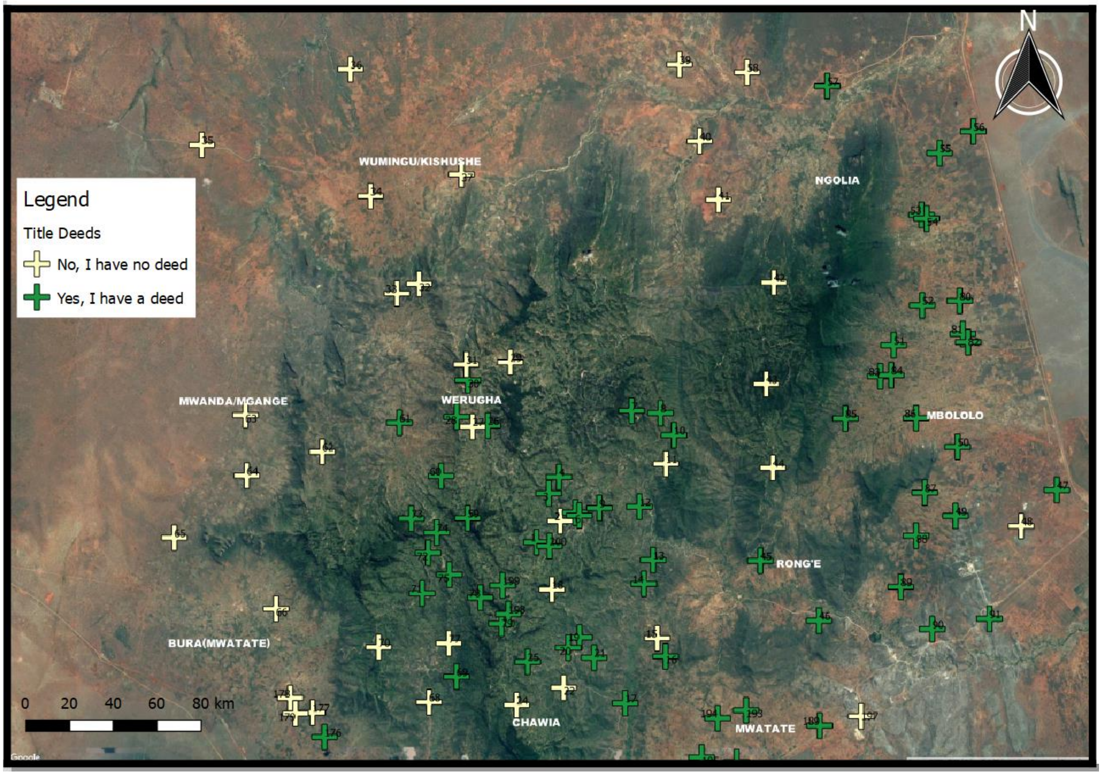

Figure 16: Title deed ownership. Source: Own illustration. Generated using QGIS

5.2.6 Livestock Ownership

The livestock rearing question in the survey considered cows, goats, sheep, chickens, donkeys and ducks. 187 of the respondents had at least one livestock animal. The livestock ownership rates show strong differences in livestock ownership between respondents through the differences between the average and the median livestock ownership. An example of this is cow ownership, where the average is 3.5 cows per person and the median is at 1 cow per person. The standard deviation for the ownership of goats, chickens and cows was extremely high due to several farmers owning 100 or more of the individual livestock. Farmers that owned lots of cows and goats were more likely to be in the lowlands and foothills, whereas farmers owning lots of chickens were more commonly in the hills. Table 6 provides a glance into the livestock ownership responses. Table 6 shows that 125 of the respondents own at least one cow and 136 of the respondents own at least one goat. Respondents who owned cows were most likely to only have one cow, whereas respondents who owned goats were most likely to have 11 or more goats.

Table 6: Livestock ownership statistics. Source: Own illustration

		Livestock Ownership					
		Cows	***Goats***	***Sheep***	***Chickens***	***Donkeys***	***Ducks***
Data Statistical Analysis	Sum	706	1443	296	1797	29	28
	Average	3.5	7.3	1.5	9	0.1	0.1
	Median	1	3.5	0	6	0	0
	Std. Dev	10.8	13.5	5	12.5	0.8	1.1
Number of households owning X of each livestock	X=0	75	64	155	26	188	196
	X=1	31	10	7	8	7	0
	X=2	36	12	8	12	1	1
	X=3	16	14	6	11	1	0
	X=4	11	19	5	22	1	0
	X=5	8	15	3	12	0	0
	X=6 to 10	14	32	12	65	2	2
	X=11+	9	34	4	44	0	1

The most commonly owned livestock by number were chickens, goats and then cows. Sheep were less prevalent, and donkeys and ducks were even less frequent. Figure 17 on the following page shows each individual livestock animal as a percentage of the total livestock ownership from all respondents combined.

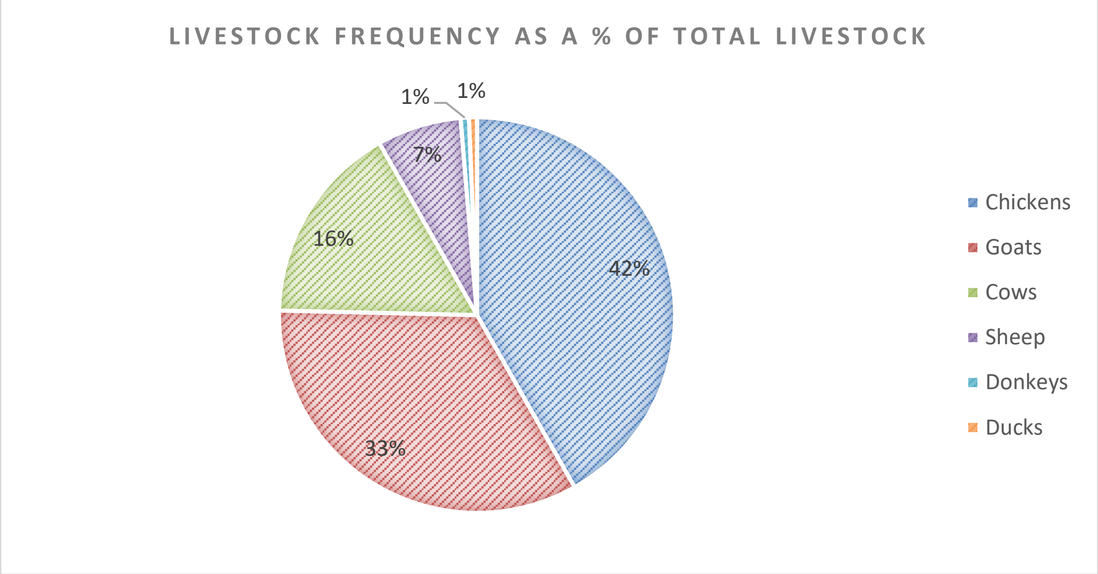

Figure 17: Source: Own illustration

5.2.7 Crops

Out of the 200 households, 178 planted crops. The most common crop was maize, which was grown by 173 of the respondents. Crop variety depended heavily on location, with those living in different geographical and ecological conditions planting different crops. Maize was seen in both the high and lowlands, whereas crops such as kale, bananas, sugar cane and avocadoes were seen only in the highlands. In the lowlands, green grams, pigeon peas and French beans were most common. Figure 18 shows the number of respondents that planted each crop.

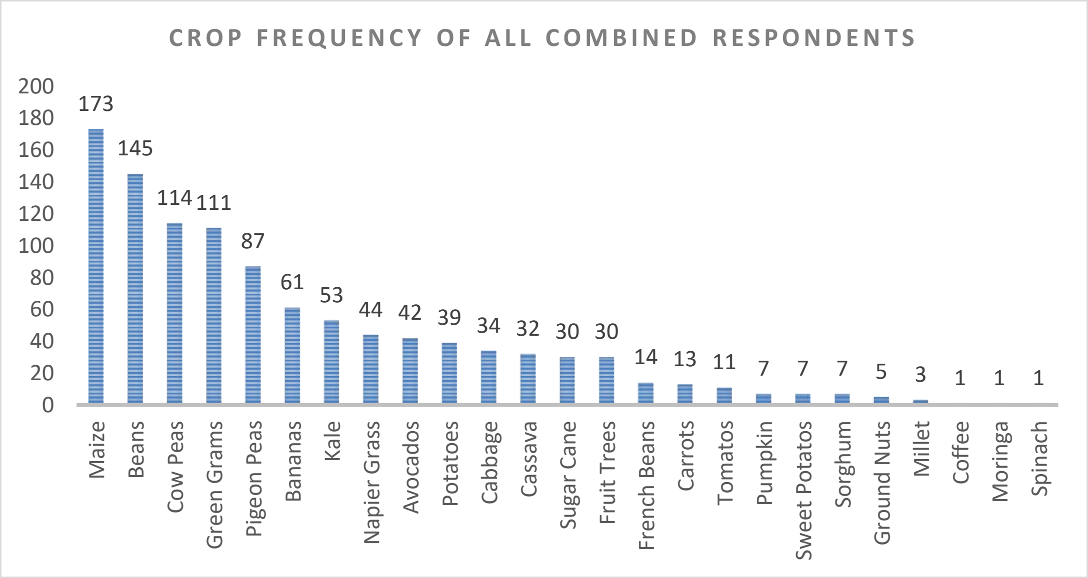

Figure 18: Source: Own illustration

Out of the 200 households, 5 households did not plant crops or have any livestock. The reasons for this were either due to recently moving, physical disability or the recent unsuitability of the land due to climatic conditions.

5.2.8 Associations and Groups

Out of the 200 respondents, 110 reported that they had some sort of community involvement through groups or projects. The most commonly reported groups were microfinance groups, community development projects, and women's groups. Due to the open-ended nature of the question, it is likely that the results received from this question are far from comprehensive. Table 7 lists the groups and associations that the respondents reported being a part of.

Table 7: Association and group membership. Source: Own illustration

Occurrences	*Group or Association Type*	*Occurrences*	*Group or Association Type*
45	Microfinance group	2	Village Leader
34	Community development projects	2	Table banking
19	Women's group	2	Spiritual guidance leader
3	Worldvision	2	Ranch
3	Self-help group	1	USAID
3	Agribusiness development	1	Teachers circle
3	National Youth Service	1	Orphan social group
3	Village Elder	1	Group lottery
3	Water projects	1	Dairy consumers

When it comes to gender involvement, women were more likely to report involvement in community groups, with 57% of women reporting involvement and only 52% of men reporting involvement in community groups or associations. The most commonly reported groups and associations by a large margin were microfinance groups, community development projects and women’s groups. Microfinance groups were generally either table banking or merry-go-rounds. Women’s groups were generally either microfinance groups or craft groups that were meant to generate additional household income.

5.3 Biogas Knowledge and Energy Usage and Capacity Results

5.3.1 Energy Usage

178 of the respondents reported using wood fuel for heating and cooking and 148 reported using charcoal. Respondents generally used multiple sources for heating and cooking, and traditional biomass sources were by far the most common source. 37 respondents said that they used gas and 12 said that they used paraffin. Most of the respondents using gas and paraffin additionally reported using traditional biomass. Two households reported using electricity and one household reported using biogas for heating and cooking. Figure 19 shows the breakdown of fuel sources used for heating and cooking. Note that the values are greater than 200 because many respondents used multiple energy sources.

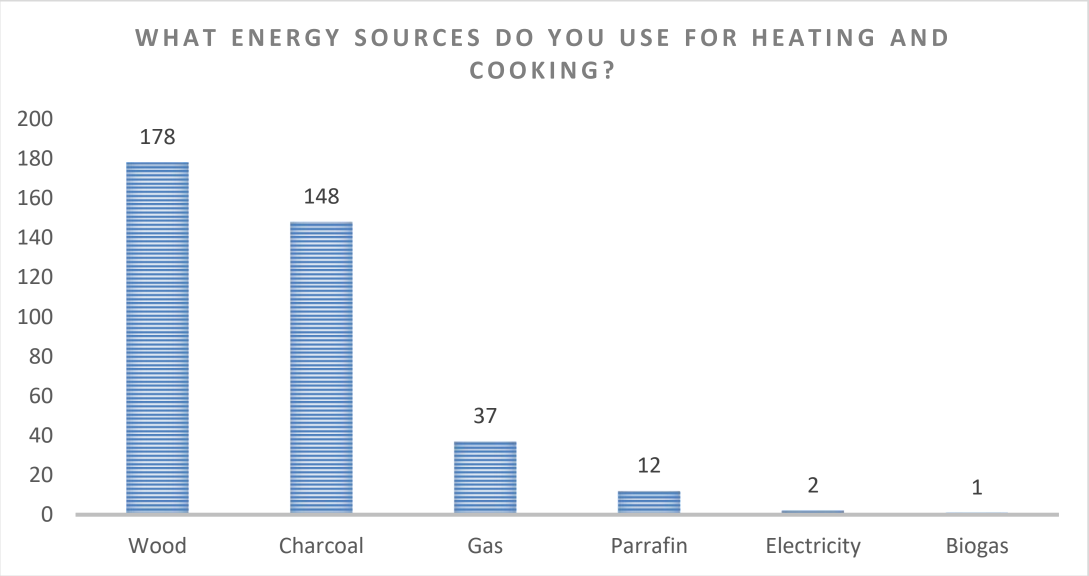

Figure 19: Source: Own illustration

The most common energy sources for both lighting and cooking were solar and electricity. Additionally, 64 respondents reported using paraffin fuel for lighting. Very few respondents reported using D-cells. Figure 20 on the following page shows the distribution of the respondents lighting and electronics sources. Not everyone that was surveyed had access to electricity. 99 of the respondents stated that they had access to electricity and 70 responded that they used it. The remaining 101 respondents had no access to electricity. 35 of those stated that it was too expensive to use even if they had access and 66 stated that they would use electricity if it was available.

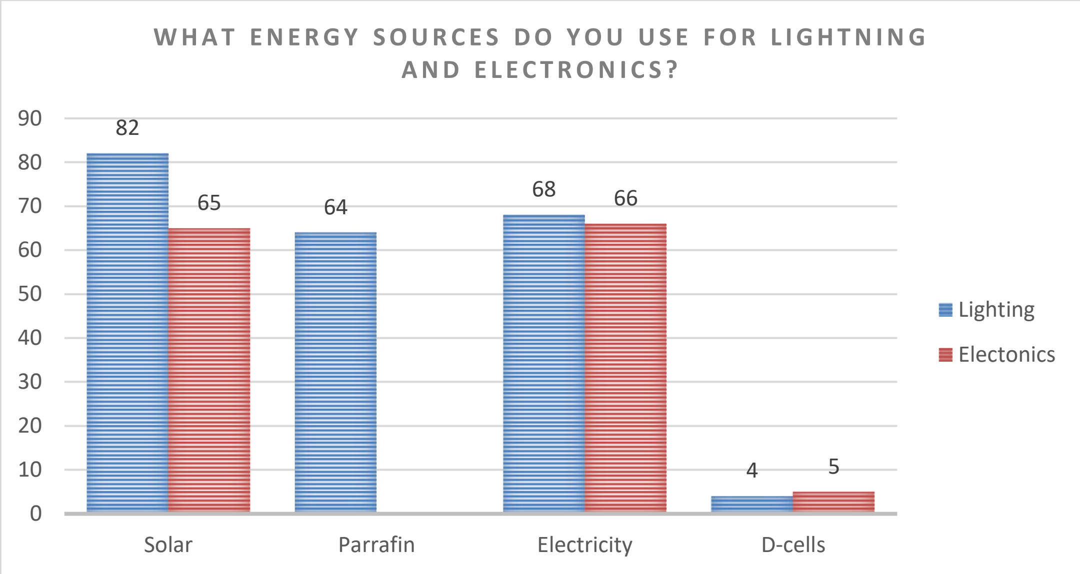

Figure 20: Source: Own illustration

Respondents spent an average of KSH 1,385 monthly on energy. Each household had a different bundle of energy, with some making no purchases and some purchasing several types of fuel each month. The energy costs for each energy type varied by region and household depending on availability and distance. Table 8 lists the average monthly cost for each energy source by each household. Note that households who did not pay money for that energy type are not included in the average price, which means that the median only considers the households that purchase the given energy source.

Table 8: Total spent on individual fuels monthly. Source: Own illustration

	Wood	***Charcoal***	***Gas***	***Electricity***	***Paraffin***
Respondents (#)	39	116	38	67	63
Average Spent (KSH)	1323	1068	737	724	397
Median Spent (KSH)	1000	1000	700	500	300
Std. Dev	977	878	487	685	266

5.3.2 Firewood Collection

Out of 200 respondents, 175 households collected firewood. Figure 21 on the following page shows the average time spent weekly by household members to collect firewood. Most households collected firewood between 1 to 3 and 3 to 5 hours a week.

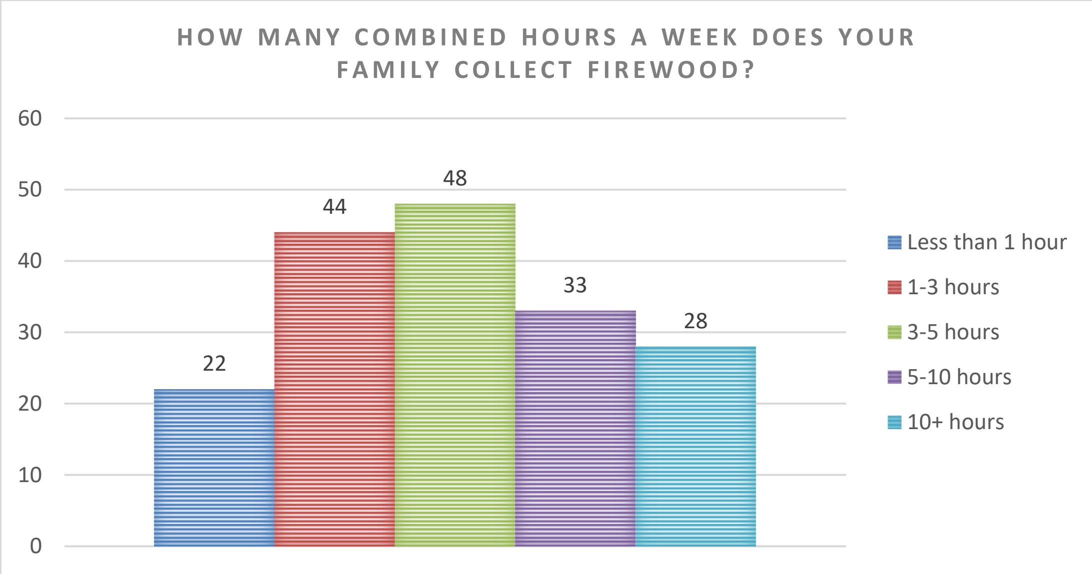

Figure 21: Source: Own illustration

Within households who collected firewood, 172 gave answers regarding who in the family collected it. The average household had 1.6 members who collected firewood on a weekly basis. Table 9 shows the age and gender distribution of the family members reported to collect firewood. In all age groups, women were more likely to collect firewood than men.

Table 9: Family Members responsible for firewood collection
Source: Own illustration

n=301	*Male*	*Male % Total*	*Female*	*Female % Total*
0 to 12 years	9	3%	14	5%
13 to 18 years	33	11%	48	16%
19 to 64 years	57	19%	123	41%
65 and older	7	2%	10	3%

5.3.3 Organic Waste Potential

The respondents were asked about their daily potential of collecting organic waste scraps from their garden and kitchen. The question was asked using buckets rather than weight to try and get more understandable data from the wide demographic of respondents. Table 10 on the following page shows the organic potential respondents expect that they can collect daily from their kitchens and gardens.

Table 10: Garden and Kitchen Scrap Potential: Source: Own illustration

	Garden Scraps	***Kitchen Scraps***
Less than 1/4 of a bucket	95	155
1/4 to 1/2 of a bucket	28	33
1/2 to 1 bucket	40	10
1 to 2 buckets	31	1
2 or more buckets	6	1

It should be noted that, even when combining kitchen and garden scraps, less than one quarter of the respondents had one or more buckets of organic scraps per day. Regarding what households did with organic waste that they wouldn't consume, 165 respondents stated that they used it as animal feed. 18 respondents used it as compost and 17 respondents said they simply disposed of it or that they burned it. 151 of the respondents said that they collected animal dung to be used as fertilizer. 10 more respondents collected cow dung for either selling, charcoal burning or biogas usage. 14 respondents that had cows and 18 respondents that had goats didn't collect the animal dung.

5.3.4 Biogas Knowledge and capacity

Out of the respondents, 51 responded that they had never heard of biogas. Out of the remaining 149 respondents, 7 said they had a negative opinion, 20 said that they had a neutral opinion and the remaining 122 said that they had a positive opinion about biogas. Most of the respondents who knew about biogas learned about it between 2011 and 2017. Figure 22 shows the years in which the respondents learn about biogas.

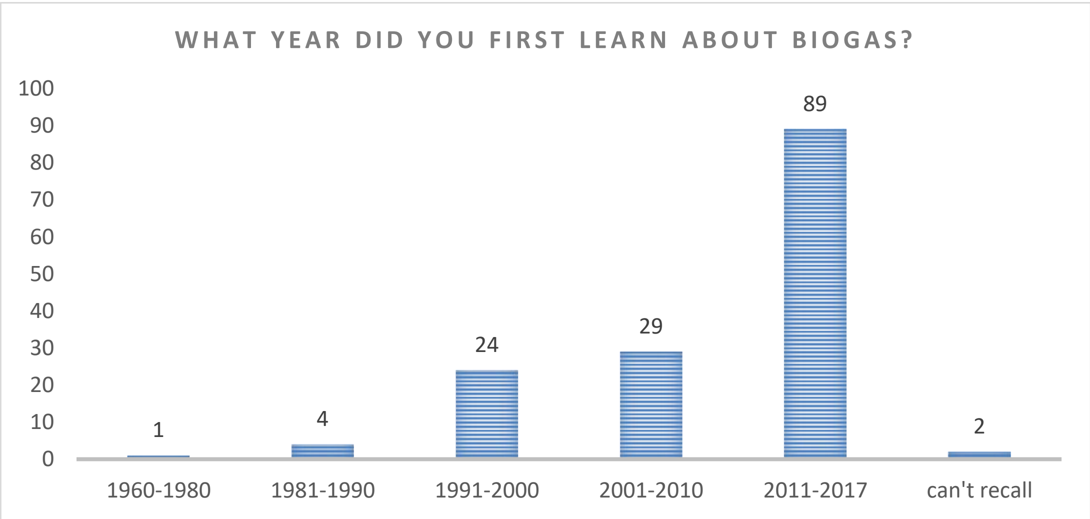

Figure 22: Source: Own illustration

Figure 23 shows the most frequent sources where the respondents learned about biogas. When considering the respondents age and where they learned about biogas, it is observed that younger respondents were more likely to have learned about biogas from primary and secondary education while older respondents were more likely to have learned through friends and neighbors. Similarly, younger respondents were more likely to be aware of biogas and have a positive opinion of it than older respondents.

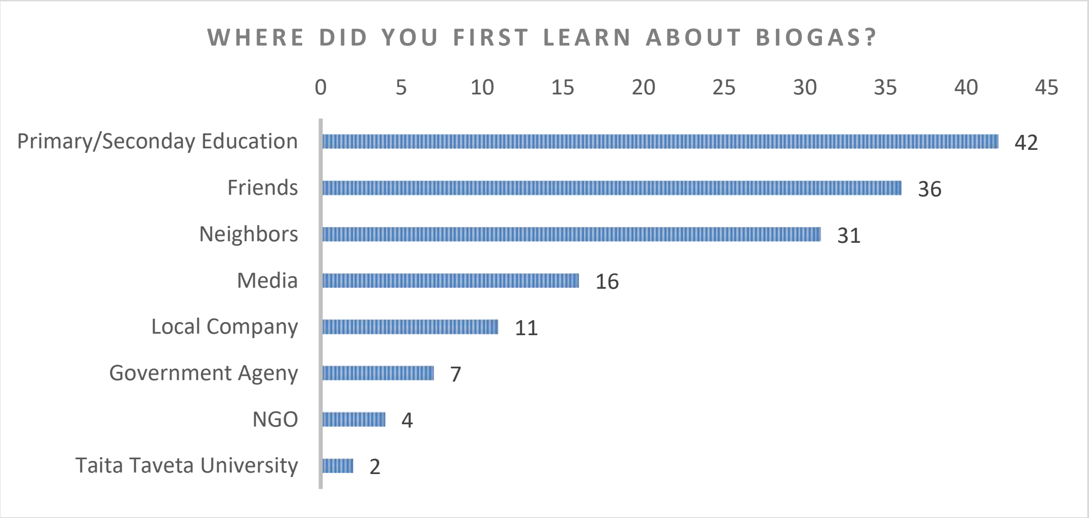

Figure 23: Source: Own illustration

The respondents who were aware of biogas were asked how much they expected a biogas system to cost to install. 95 of the respondents said they had no idea. The second most common answer was 16 respondents estimating a cost of KSH 10,000 to KSH 14,999. Figure 24 shows the price expectations of the respondents.

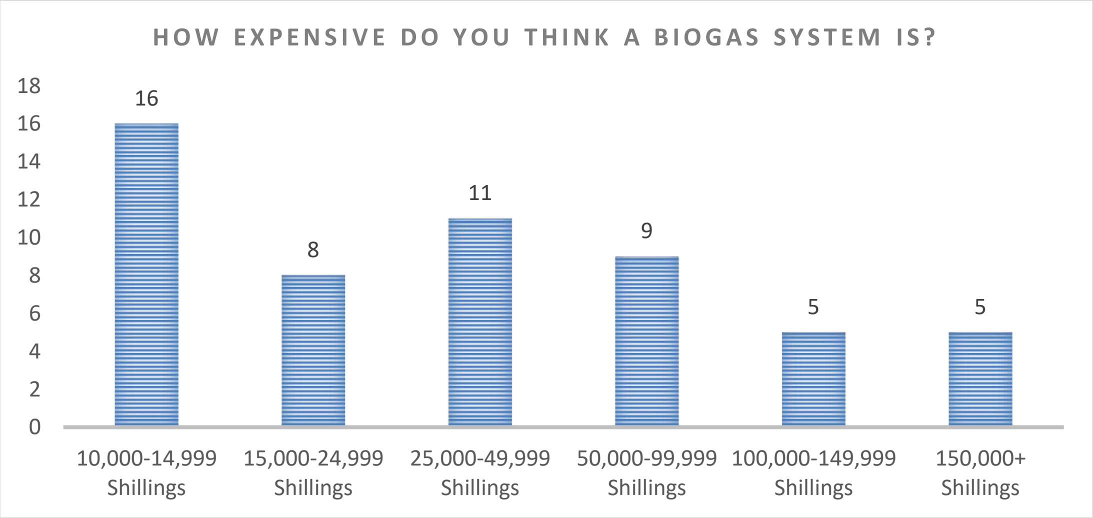

Figure 24: Source: Own illustration

The next question asked the respondents how large of a family they expected a biogas system could support. 66 respondents answered that they have no idea. The second most common answer was at 34 respondents who estimated a biogas plant could support 6 to 10 household members. Figure 25 shows the results for how many household members a biogas system can support.

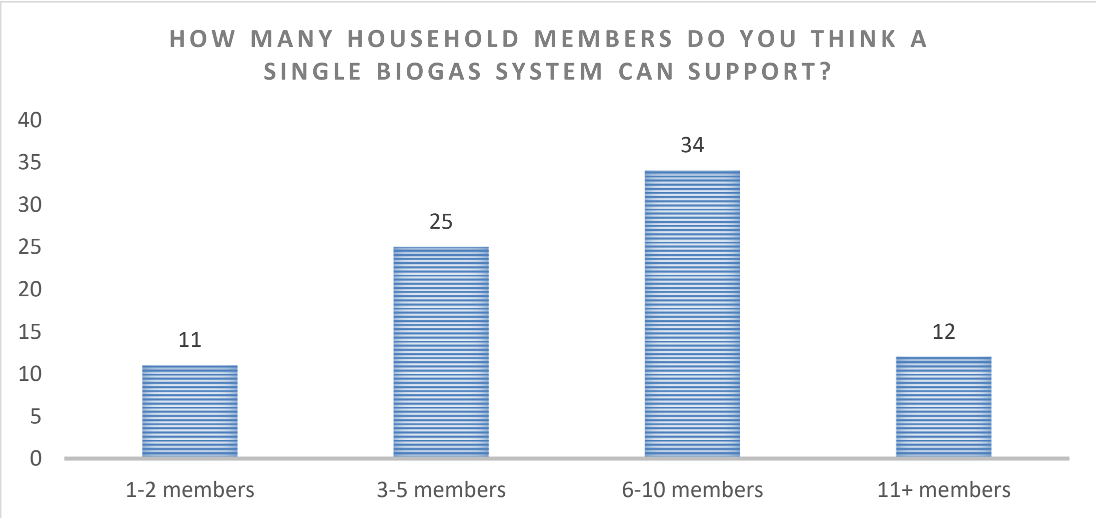

Figure 25: Source: Own illustration

The final biogas knowledge question asked the respondents whether they were aware that non-animal organic waste, such as vegetable scraps, could be used to produce biogas. 130 respondents were unaware that non-animal organic waste could be used to create biogas. Figure 26 shows the responses from the 149 respondents who answered this question.

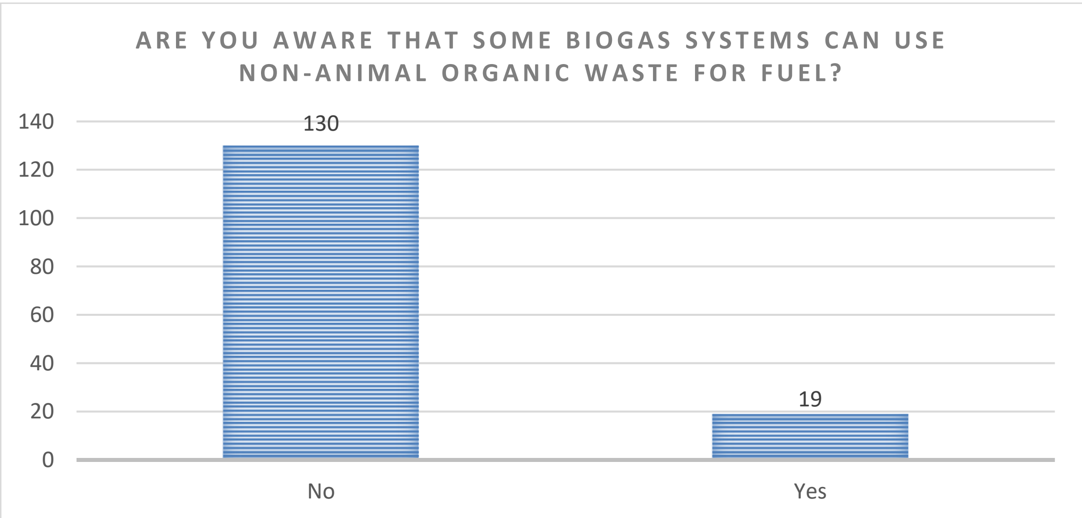

Figure 26: Source: Own illustration

The remaining biogas-related questions sought to determine the level of interest in biogas technology in the local community. 194 of the respondents said they would be interested to see a biogas plant in operation. The next question was regarding supporting the development of an energy group that could train community members to build, install, support, operate and manage biogas plants. 174 respondents said they would *absolutely* support such a group. Figure 27 shows all the responses to supporting the energy group.

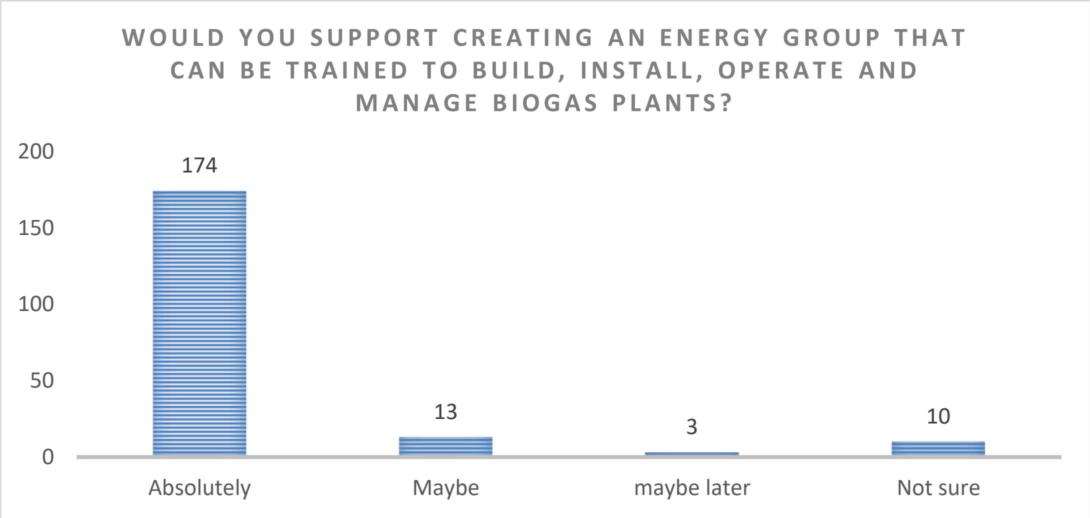

Figure 27: Source: Own illustration

When asked whether the community member would like to join the previously mentioned group, 164 respondents said they would *absolutely* like to join the group. Figure 28 shows the remaining answers to joining the energy group.

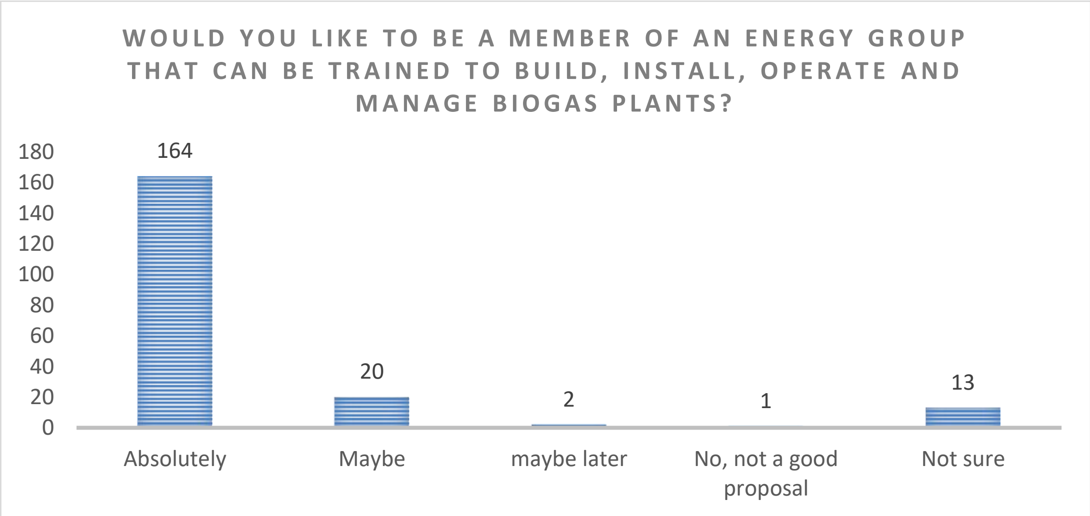

Figure 28: Source: Own illustration

The respondents were asked whether they would be willing to recommend government funding for the development of biogas technology. 91 respondents said *yes, it is extremely important*, and 76 respondents said *yes, but it's not a big priority.* The remaining respondents said either *not sure* or *no.* Figure 29 shows the responses to the government funding question.

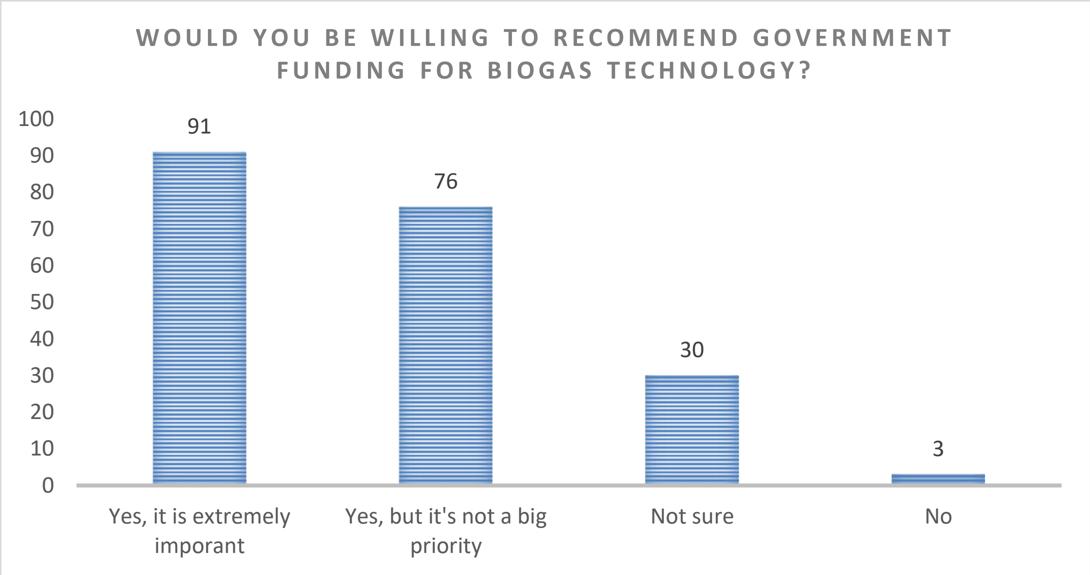

Figure 29: Source: Own illustration

5.4 Opinion Questions

5 general knowledge and opinion questions were asked to gauge the respondent's awareness and interest in several key issues that are related to biogas technology growth. These questions were focused on health, environmental and gender issues related to firewood collection and burning.

5.4.1 Are you aware about damage to forests due to firewood collection?

Figure 30 on the following page shows the respondents answers to the first question. All 200 respondents provided an answer to this question. The least common answers were *no*, and *yes, and I am not at all concerned*. 19 respondents answered *yes, and I am not very concerned*. The most common answer given was 135 respondents answering *yes, and I am concerned.* 28 respondents responded with *yes, and I am very concerned.*

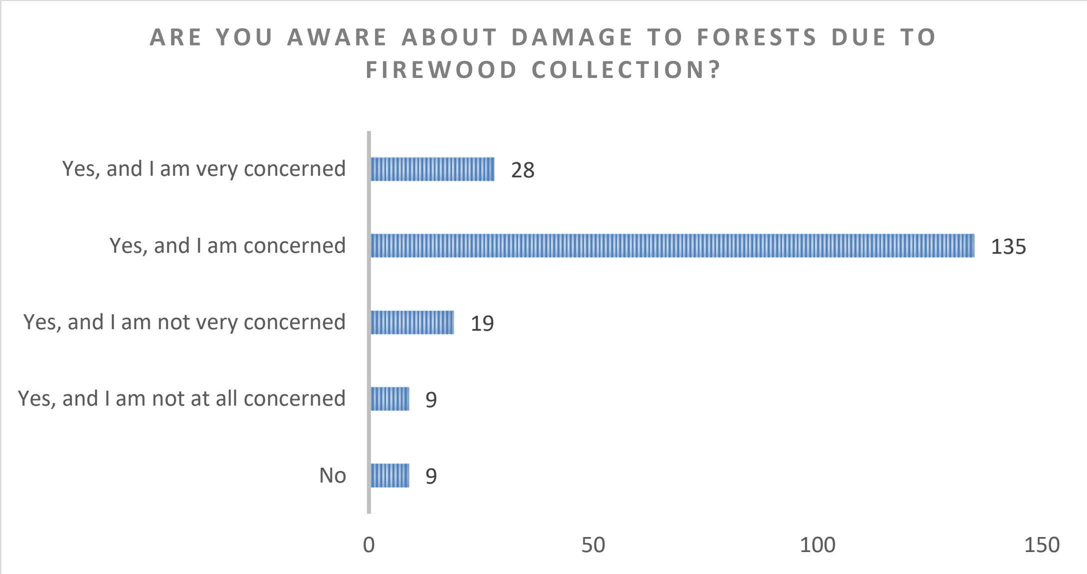

Figure 30: Source: Own illustration

5.4.2 *Are you aware of health problems related to traditional cooking stoves?*

Figure 31 shows the respondents answers to the second question. All 200 respondents provided an answer to this question. 62 respondents answered *no*, and 6 respondents answered *yes, and I am not at all concerned*. 13 respondents answered *yes, and I am not very concerned*. The most common answer given was 92 respondents answering *yes, and I am concerned*. 27 respondents responded with *yes, and I am very concerned.*

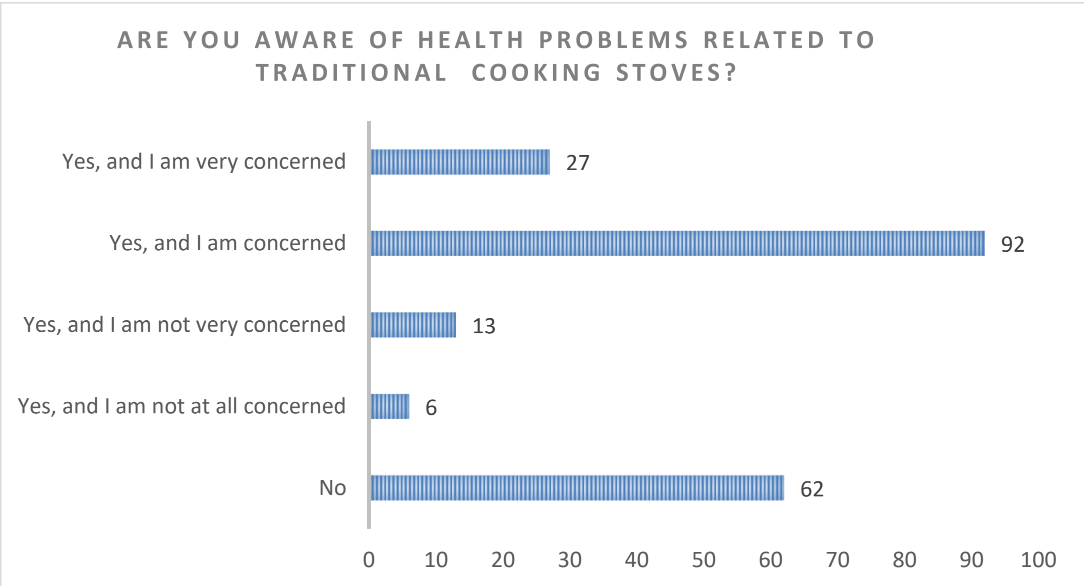

Figure 31: Source: Own illustration

5.4.3 *Do you think women and men bare equal burden when it comes to firewood collection?*

Figure 32 shows the respondents answer to the third question. 199 respondents provided an answer to this question. 7 respondents answered *no, men bare more burden and that is a problem.* 4 respondents answered *No, men bare more burden and that is okay*. 13 respondents answered *No, women bare more burden and that is a problem.* 68 respondents answered *No, women bare more burden and that is okay.* The most common answer given was 107 respondents answering *yes*, they believed women and men bare equal burden.

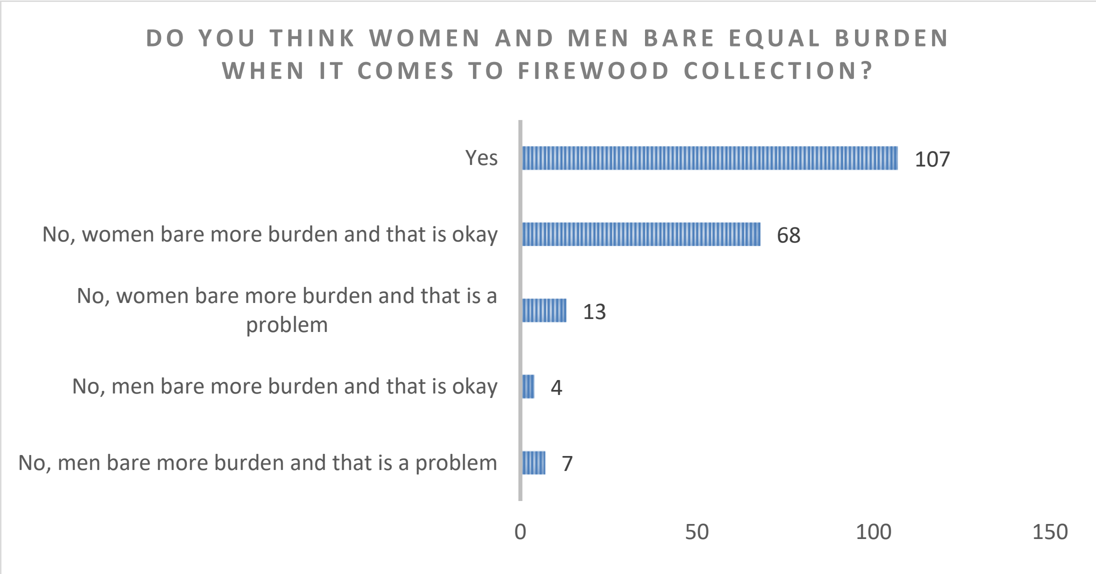

Figure 32: Source: Own illustration

5.4.4 *Do you make an effort to mitigate damage to forests?*

Figure 33 on the following page shows the respondents answer to the fourth question. All 200 respondents provided an answer to this question. 24 respondents answered *I have made large lifestyle changes to lower damage to forests*. The most common answer given was 133 respondents answering *I try to make small changes to lower damage to forests.* 5 respondents answered *No, I do not have time or energy to consider it.* 38 respondents responded with *No, I do not think about damage to forests.*

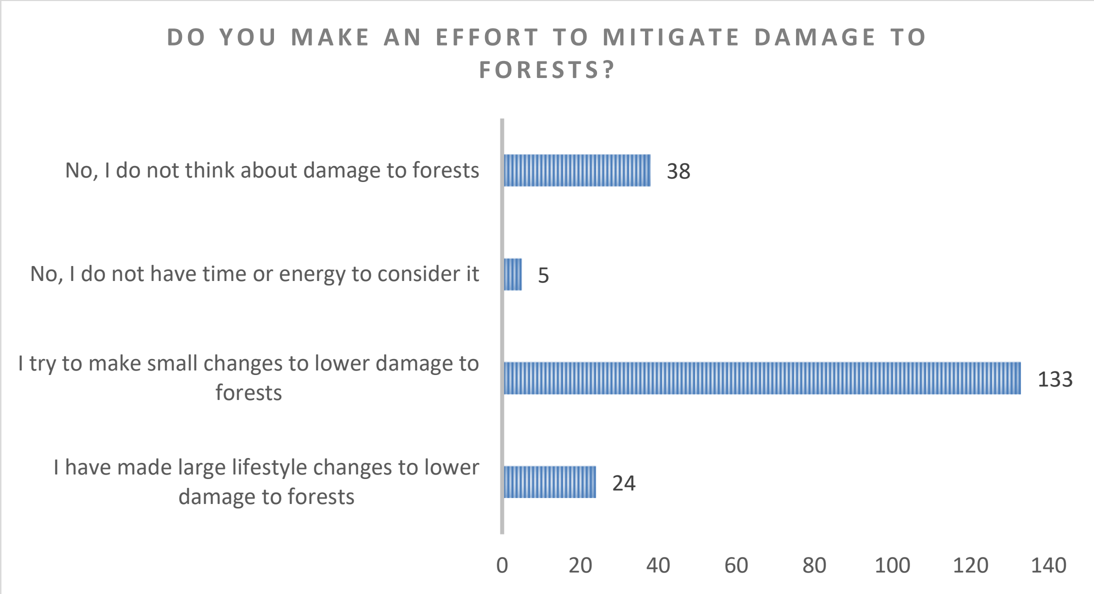

Figure 33: Source: Own illustration

5.4.5 *Do you make an effort to mitigate health risks from cooking stoves?*

Figure 34 shows the respondents answer to the fifth question. All 200 respondents provided an answer to this question. 27 respondents answered *I have made large lifestyle changes to lower health risks from wood smoke*. The most common answer given was 96 respondents answering *I try to make small changes to lower health risks from wood smoke*. 2 respondents answered *No, I do not have time or energy to consider it.* 75 respondents answered *No, I do not think about it*

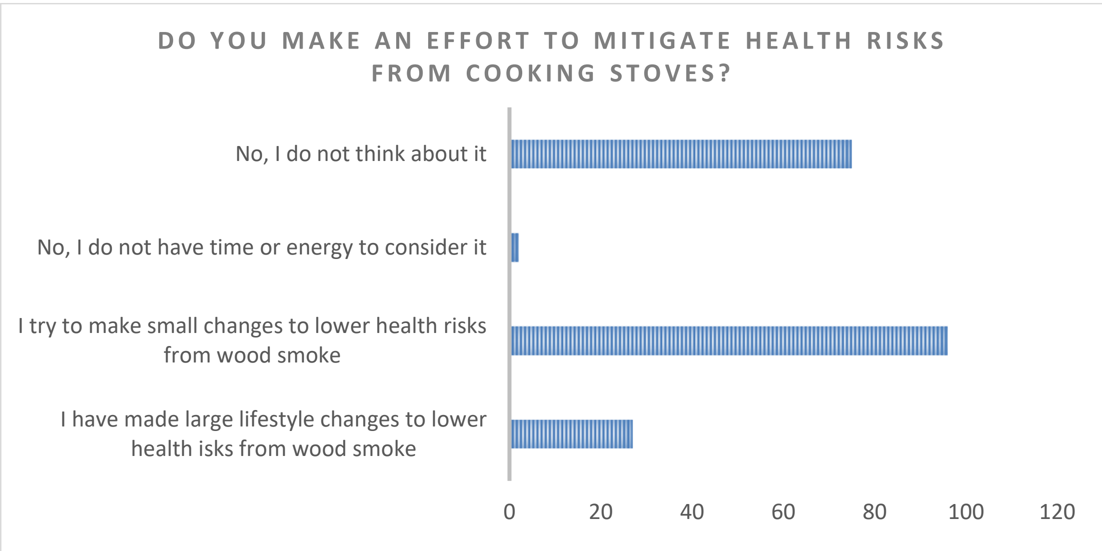

Figure 34: Source: Own illustration

5.5 Personal Comments

Respondents could give personal comments, questions or concerns regarding biogas, our project, or any related subject matter. The following section includes a brief list on concerns, questions and suggestions from respondents.

I. *Many respondents were concerned that they would only be able to generate enough scraps and wastes seasonally.*
II. *Many respondents were curious about the price of a biogas system.*
III. *Many respondents were eager to learn about and potentially adapt biogas technology.*
IV. *Several respondents recommended we speak with their village chiefs to gain their support and interest in the project.*
V. *Several households were interested in the idea of selling biogas to neighbors.*
VI. *Several respondents were curious if bringing biogas technology would provide employment opportunities for the local community.*
VII. *Several respondents were concerned with the durability of biogas systems.*
VIII. *Several respondents were concerned about the potential hazards of biogas.*
IX. *One respondent was concerned about having to search for manure.*
X. *One respondent was concerned about the security from thieves taking components.*

6 Discussion

6.1 Introduction

In this chapter the relevant results from the questionnaire will be discussed alongside their relationship to the literature. RQ 1 and RQ 2 were previously answered in the literature review section and this discussion seeks to combine the knowledge gained from those two sections to answer RQ 3. In this chapter the literature will be used to provide a knowledge base to use along with the data from the results section. The total biofuel potential for the respondents will be calculated along with the current income and savings potential for each of those farmers who have enough fuel to support a biogas system. The goal is to try and get an estimate on the potential for biogas development in the region.

6.2 Discussion

6.2.1 Potential Regional Benefits

Taita Taveta County is right in line with the data from Ndegwa et al. (2011) that shows that approximately 90% of rural households in Kenya use firewood as a primary cooking source. In the collected data, 178 of the respondents used firewood and 148 additionally used charcoal. Since 175 of these households also collected firewood, biogas adoption has great potential to reduce deforestation, and further to reduce the occurrence of droughts, floods and landslides, all of which potentially increase through deforestation (Mwesigye et al., 2011). Similarly, the region has a great potential for reducing the HAP and reaping the health benefits, including decreased occurrence of breathing problems (Dohoo et al., 2013), frequency of high blood pressure (Baumgartner et al., 2011) and stroke (WHO, 2016). Women and young children would also benefit from adoption of biogas through the reduction of very early neonatal mortality (Patel, et al., 2015) and the reduced burden on women, who presently spend more time each week collecting firewood.

While energy policy is frequently genderblind, the results from this questionnaire were similar to those from the 2014 KENDBIP survey (Nyamu, G. 2014), which showed women were more likely to have the burden of collecting firewood at every age bracket. This data is also consistent with the literature that proposes that the woman is the primary energy provisioner (Clancy & Stockbridge, 2017). Because they are the primary energy provisioner, adopting favorable biogas policy and developing biogas infrastructure to better disseminate biogas technology in Taita Taveta has great potential to improve the livelihood of women. The study results also show that 60% of the illiterate respondents were women. Considering the variety of ages, these results are consistent with UNICEF findings from 1974 that showed girls making up only 43% of total primary school enrollment. It is important to note, that this gap has now disappeared in primary school, however it still exists in secondary school, albeit at a lower rate (United Nations, 2018). Since the questionnaire asked for household income rather than individual income, there were not enough respondents to compare the income from single men and single women.

6.2.2 Regional Knowledge

From the literature, most biogas development took place in developing nations throughout the 1970s to mid-1980s, but this wasn't the case in Kenya, with only an estimated 850 household biogas plants installed in Kenya by 1995, and only a 25% operational rate of those plants (Gitonga, 1997). This result is evident in the data, with only 1 respondent saying they knew about biogas prior to the 1980s. Most of the respondents said they learned about biogas within the last few years from 2011-2017, which is consistent with the relatively late growth of household biogas in Taita Taveta. Most respondents learned of biogas from primary/secondary education or through friends or neighbors. The recent knowledge also aligns with the start of a local biogas company, Biogas Taita, in 2009.

Sovacool et al. (2014) noted that early failures of biogas projects occasionally led to negative stigmas towards biogas, due to failed pilot projects or general skepticism. In the questionnaire, only 7 respondents said they had a negative opinion of biogas, with most of the remaining having a positive opinion. These results are similar to those from a 2009 survey by Mwirigi et al. (2009). In the questionnaire, only 75% of the respondents were aware of what biogas was. This is further supported by literature, with Sovacool et al. (2014) noting lack of knowledge and lack of money being the largest causes for the slow dissemination rates of biogas technologies in Kenya. Similarly, Sovacool et al. (2014) determined that the largest bottleneck leading to a lack of biogas adoption is the initial investment cost. Household biogas plants generally range from 40,000 KSH to 120,000 KSH for installation. Their research suggests that a fixed dome biogas system will cost approximately 100,000 KSH, a floating drum biogas system will cost between KSH 90,000 to KSH 120,000 and a flexi biogas system will cost between KSH 40,000 and KSH 80,000. (Sovacool et al., 2014).

These prices vary greatly by region. In Taita Taveta, Biogas Taita has been producing fixed biogas plants using local labor and resources. Biogas Taita offers prices ranging from KSH 98,000 for a $6m^3$ to KSH 141,000 for a $12m^3$ digester (Biogas Taita, 2018). Flexi-style biogas systems haven't made headway in Taita Taveta, and thus fixed dome biogas systems make up almost all the installed biogas plants. Despite this, out of the 54 respondents who estimated the price of installing a biogas plant, the largest portion of them (16) believed it was between KSH 10,000 and KSH 14,999. 35 total respondents believed the price would be below KSH 49,999. These price estimations are far below the actual price of a biogas system in Taita Taveta. One potential reason for the lack of price knowledge is due to the historical subsidies that made biogas installation cheaper leading to knowledge distortion.

The price wasn't the only fact that was deeply misunderstood by the respondents. Traditional biogas systems used just animal manure, but recent technology developments have led to non-animal organic waste being usable to create biofuels, yet, out of 149 respondents that were aware of biogas, 130 were unaware that non-animal organic waste could be used for biofuels. This is even more surprising since Biogas Taita advertises that non-animal organic wastes can be used in some of their systems (Biogas Taita, 2018).

Most respondents were very interested in learning about and seeing biogas technology. 194 respondents said they would like to see a plant in operation. The respondents were also very supportive of the idea of creating and even joining an energy group that could be trained to build, install, operate and manage biogas plants. The local support for biogas is a requirement to the success of a development project, since they are both the supplier and the producer of biogas. If a farmer isn't interested or invested in the technology, they will not maintain the system well and there is a high likelihood of failure (Ni & Nyns, 1996). Additionally, farmers are rational and only willing to adopt a new technology if they believe the utility is greater than that of the traditional technology (Feleke & Zegeye, 2006). The large majority of the respondents reported that they were entirely willing to support and participate in biogas technology development.

6.2.3 Opinion Questions

The five opinion questions previously introduced in the data section were attempting to gauge the respondent's awareness and concern of environmental, health and social implications of fire wood collection and cooking. While it will not be deeply discussed, in Appendix I.2 the opinion questions are further divided according to the respondent's education level, age, and gender. The responses to the questions in this section are briefly examined to determine if their responses can be used as knowledge to guide any future actions.

6.2.3.1 Are you aware about damage to forests due to firewood collection?

In this question, the most common answer was *yes, and I am concerned.* There was no large disparity between respondents of different age or gender. Education level was significant, with those with vocational training having much higher rate of responding *yes, and I am very concerned*. Respondents who had received secondary education had the second highest rate of responding with *yes, and I am very concerned*. Since only three respondents had university experience, there isn't enough data to conclude anything. This increased *yes, and I am very concerned* response rate may be due to the additional technical education that the respondents had received. Overall, a clear majority of the respondents are aware and concerned of damage to forests. Respondents occasionally mentioned local climate change effecting the frequency of rains and ephemeral rivers, as well as an increased firewood collection time. Firewood collection can take longer due to either deforestation or forested areas becoming part of programs such as the Community Forest Associations (CFAs). CFAs have been established in Taita Taveta county to better facilitate sustainable forestry management (TTCG, 2013).

6.2.3.2 Are you aware of health problems related to traditional cooking stoves?

The most common answer for this question was *yes, and I am concerned*¸ and respondents who had received secondary education and vocational training were more likely to say *yes, and I am very concerned.* There was no other major disparity in the responses based on age or gender. There was a surprising number of respondents who answered *no* to this question. More than 30% of the respondents said that they were not aware of health problems related to wood cooking stoves. In literature, HAP is widely discussed, but within the region it doesn't seem to be well understood by all the respondents. At the same time, several respondents reported negative health effects on themselves or family members due to smoke inhalation. Regarding local knowledge about HAP, within the Taita Taveta County Integrated Development Plan from 2013-2017, there is no direct mention of either IAP/HAP, smoke inhalation, or cook stoves (TTCG, 2013). At the same time, IAP management is listed in the Taita Taveta Community Development Plan for 2016/2017 and the lack of knowledge and ignorance about pollution is listed as one of the challenges the region faces (Masawi, 2015).

6.2.3.3 Do you think women and men bare equal burden when it comes to firewood collection?

The most common answers for this question were *yes*, and then *no, women bare more burden and that is okay.* While it wasn't a major difference, those with a secondary education and vocational training were more likely to say *yes* as opposed to *no, women bare more burden and that is okay.* There were no major differences based on age. Women were more likely to believe that they bore more burden, but most women said *No, women bare more burden and that is okay. Yes* being the most common answer is not consistent with the results from the questionnaire which asked about who in the family collected firewood. Women at every age bracket were more likely to collect firewood.

6.2.3.4 Do you make an effort to mitigate damage to forests?

The most common answer to this question is *I try to make small changes to lower damage to forests.* Respondents with secondary education and vocational training were more likely to say *I have made large lifestyle changes to lower damage to forests*. Men were more likely to answer with *I have made large lifestyle changes to lower damage to forests* than women. While the question didn't ask directly for those changes that were made, lifestyle changes that were mentioned generally included planting trees, harvesting only dead wood, changing cooking habits or changing cooking fuels.

6.2.3.5 *Do you make an effort to mitigate health risks from cooking stoves?*

The most common answer for this question is *I try to make small changes to lower health risks from wood smoke*. Respondents who had received secondary education or vocational training were much more likely to answer *I have made large lifestyle changes to lower health risks from wood smoke.* Males were slightly more likely to answer *I have made large lifestyle changes to lower health risks from wood smoke.* Respondents mentioned changes such as installing chimneys, using charcoal for faster cooking, switching to gas or paraffin, using a smoke house, cooking outdoors, or waiting outdoors as the food cooks. Consistent with the 30% of the respondents who had no idea that wood smoke could have a negative health effect, approximately 37% of the respondents said that they do not think about it mitigating health risks from cooking stoves.

6.2.4 Regional Potential

The previous subsections have exposed the potential benefits and degree of local knowledge. The remaining subsection seeks to determine the regional potential for biogas technology development and spread, considering both the financial and the organic waste potentials of the respondents.

6.2.4.1 Financial Potentials

The data shows a significant relationship between a household's income and their reported ability to save. While this is obvious, it is important to gauge a family's relative ability to save rather than just their income. The standard and cost of living for families varies drastically depending on their circumstances, fuel usage, and location. Out of the 195 respondents, only 15 respondents said they can set aside at least KSH 2,500 every month. 35 additional respondents said that they could save between KSH 1,000 and KSH 2,499 every month. Figure 35 on the following page shows the distribution of incomes to savings ability of each of the households.

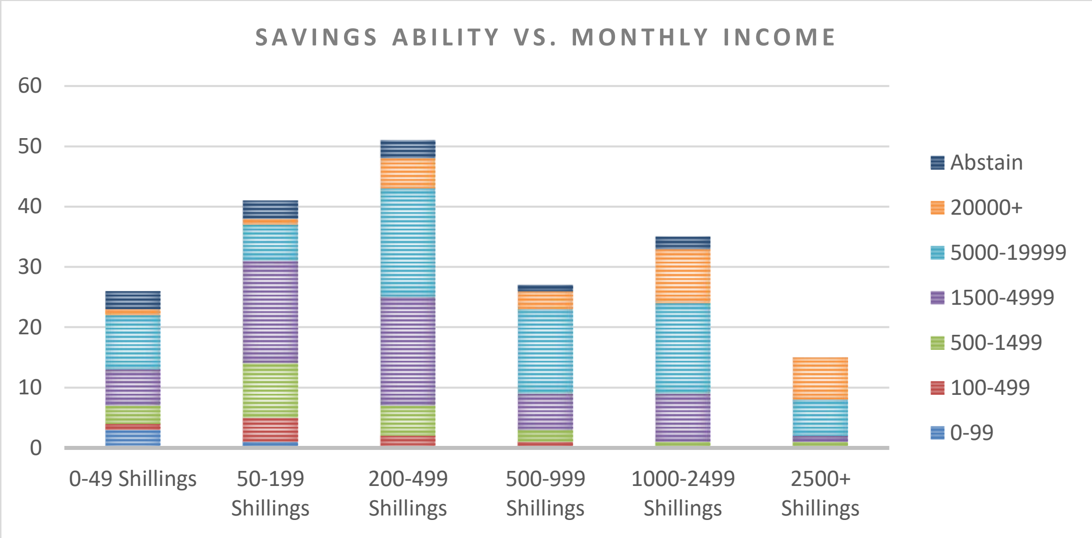

Figure 35 Source: Own illustration

With 75% of the households not being able to save KSH 1,000 per month, it is understandable that individual households are not able to afford biogas technology, which in the region costs approximately KSH 100,000.

6.2.4.2 Organic Waste Potentials

To determine the overall biogas production potential in the county, each of the respondent's animal waste and vegetable waste have been summed to estimate the expected potential daily biogas production of each individual household. The number was generated using the sum of each household's organic waste results. The calculations were done using estimations for biogas coefficients for each individual waste product. For the purposes of the study, a full bucket of kitchen scraps or garden scraps was assumed to weigh 10kg. Table 14 on the following page shows the biogas coefficients that were used and the calculated biogas yield per unit of input per day. The method of using a biogas coefficient was used because getting exact values would be impossible due to the variation of input quantities and varieties. Additionally, biogas systems do not all operate at the same efficiency, with newer systems such as the FBS (Sovacool et al., 2014) and the Nagaro Smart Biogas system (Khan, A. 2017) boasting a much higher efficiency.

Table 11: Values used to estimate biogas production capabilities. Source: Own illustration.

Unit	*Ton Per Year (dung or scraps)*	*Biogas coefficient (m^3/y/t)*	*Biogas Yield Per Unit Per day (M^3/t/day)*	*Source*
Cow	3.6	33	0.325479452	(Tatlidil, Bayramoglu & Akturk., 2009)
Goat	0.7	58	0.111232877	(Tatlidil et al., 2009)
Sheep	0.7	58	0.111232877	(Tatlidil et al., 2009)
Chicken	0.022	78	0.00470137	(Tatlidil et al., 2009)
Donkey	1.4	33	0.126575342	Low estimations using data from (Mukumba et al., 2016) and (Wise et al., 1986)
Duck	0.022	78	0.00470137	(Tatlidil et al., 2009)
Kitchen Scraps (1 bucket)	4.0234315	169.609	1.869616968	(Msibi & Kornelius, 2017)
Garden Scraps (1 bucket)	4.0234315	60	0.661386	(Ngumah et al, 2013)

One weakness of this estimation is that it ignores the potential difficulty of collecting certain types of manure. Almost all the research on rural biogas production has focused on farmers using cattle manure as the main input, with additional inputs being optional. According to (Adoyo, et al., 2007) and (Porras, et al., 2015), a household should have 2 cows minimum under zero-grazing or 3 cows under semi zero grazing techniques to be able to benefit from biogas technologies. Out of all the respondents, only one was using zero grazing techniques. The questionnaire didn't record whether farmers were using semi-grazing techniques. Another weakness to this method is the difficulty of understanding the effects of co-digestion.

Co-digestion is written about heavily in literature, but there is no formula, with exception to research such as Mukumba et al. (1986), which goes through the process of co-digesting several ingredients at fixed ratios (Mukumba et al., 1986). Co-digestion between animal manure and vegetable/food waste has been found to increase biogas production through a better balance of carbon and nitrogen (El-Mashad & Zhang 2010), as well as improving the overall efficiency of the anaerobic digestion (Zhu, 2010).

Evaluating the exact biogas output isn't viable at such a large scale because individual households have a different basket of animal and non-animal wastes and the biogas systems are likely to be operating under different temperature and activity conditions. The biogas coefficient included in the table is the expected yield from a traditional biogas system, not accounting for potential increases or decreases that could occur due to co-digestion. Table 15 shows the estimated biogas yield per day per household for each of the 200 respondents.

Table 12: Biogas yield per day

Biogas Yield Per Day	***Households***
Less than one m^3	63
Between 1 m^3 and 2 m^3	61
Between 2 m^3 and 3 m^3	25
Between 3 m^3 and 4 m^3	21
Between 4 m^3 and 5 m^3	7
Between 5 m^3 and 6 m^3	9
Greater than 6 m^3	14

The average monthly energy cost of respondents is KSH 1,386. The largest costs are due to cooking and lighting fuel and average KSH 1,143 a month. In addition, most families spend around 12 to 20 hours collecting firewood each month, with some collecting firewood for more than 40 collective hours in a month. Many of these families have enough substrate that they could benefit financially and save a lot of combined hours each month by adapting biogas technology. It is impossible to predict an exact potential savings rate on fuel since users that adopt biogas often still use alternative fuels, however, Lekule (1996) estimated that adopting biogas can reduce wood fuel consumption by up to 60%.

According to (Nyamu, 2014), users who cook with biogas take an average of 3 hours a day to cook. Most biogas cookstoves consume anywhere from 0.22 to 1.1m^3 biogas per hour. Biogas lamps consume between 0.07 and 0.14 m^3 of biogas per hour (Karki, 2001). There isn't any specific data about the biogas consumption per person from Kenya, although the data is available from Sudan and India which suggest 0.425 m^3 per day (Omer & Fadalla, 2003) and 0.34-4.2 m^3 per day, respectively (Singh & Sooch, 2004).

Following receiving the biogas yield per household, that number was divided by the size of the households. Out of the respondents, 84 households had potential to produce at least 0.42 m^3 of biogas per person. Assuming the biogas usage rates per person are similar to those in Sudan and India, those 84 households, with the right infrastructure development, should have enough material to switch their predominant cooking fuel to biogas.

6.2.4.3 Combined Potentials

Table 16 provides the demographics of the 84 households that were able to produce at least 0.42 m^3 of biogas per day per person. Within Taita Taveta, there was no shortage of people interested and willing to try biogas. There was a shortage of people who had the means to afford a biogas system, with only 27 of the respondents who could produce at least 0.42 m3 of biogas per person per day being able to save at least KSH 1,000 monthly.

Table 13: Demographics of respondents who produce >0.42 m^3 per day per household member. Source: Own illustration.

	Demographic	*Percentage of Total*	*Total Respondents*
Education	Illiterate	8.33%	7
	Primary Education	46.43%	39
	Secondary Education	30.95%	26
	Vocational Training	11.90%	10
	University	2.38%	2
Age	15-25	17.86%	15
	26-35	22.62%	19
	36-45	14.29%	12
	46-55	21.43%	18
	56-65	16.67%	14
	66+	7.14%	6
Gender	Female	55.95%	47
	Male	44.05%	37
Profession	Business Owner	15.48%	13
	Employed	8.33%	7
	Farmer	58.33%	49
	Student	5.95%	5
	Unemployed	8.33%	7
Income	0-99	2.38%	2
	100-499	3.57%	3
	500-1499	8.33%	7
	1500-4999	25.00%	21
	5000-19999	34.52%	29
	20000+	23.81%	20
Montly Savings Potential	0-49 Shillings	14.81%	12
	50-199 Shillings	17.28%	14
	200-499 Shillings	19.75%	16
	500-999 Shillings	14.81%	12
	1000-2499 Shillings	20.99%	17
	2500+ Shillings	12.35%	10

Only 10 of the eligible respondents said that they would be able to save at least KSH 2,500 every month, which is a more reasonable estimation when considering that the price of a biogas system in the area starts at KSH 98,000. According to their responses, 10 respondents would be able to put at least KSH 2,500 a month in payments towards a biogas plant while having enough waste inputs daily. These results should be taken as indicative rather than representative, but they show a high potential for biogas development in the region. With a rural population of approximately 308,000 and 5% of that population expected to have the financial and waste potential for biogas, that means there is a potential market of approximately 15,400 farmers. Expanding the results to include people of all incomes, there would be approximately 129,500 farmers who could benefit from biogas digestion plants with the right support structure and infrastructure development.

7 Conclusion and Recommendations

7.1 Conclusion

Biogas dissemination has been relatively successful in the agricultural sector in developed nations, but not so successful in developing nations which are generally characterized by many small-scale farmers. The purpose of this research project, conducted in Taita Taveta County, Kenya, was to determine the potential capacity for and benefits from biogas development in the county. A thorough literature review was conducted, and 200 households were questioned to attempt to answer the research questions.

The two most common fuel sources in the region were firewood and charcoal, both of which have negative impacts on health, the environment, and gender equity. Successful adoption of biogas would lead to a large welfare increase for locals through environmental, health, economic and gender equity improvements. The most startling result from the study is that approximately 30% of the respondents reported that they weren't aware of the negative health effects from woodhouse smoke. This result shows a major lack of knowledge that should be reduced to immediately increase the local's health and welfare.

The local community is mostly aware of biogas and have a great interest in learning more about the technology, with 97% of the respondents saying that they would be interested in seeing a biogas plant in operation. While 75% of the respondents were aware of biogas, there was a large level of price and functionality disinformation. The results from the study show that there is a potential market for biogas development in Taita Taveta County. Based on the data from the questionnaire, it can be estimated that Taita Taveta County has approximately 15,400 farmers who could benefit from adopting biogas technology without the need for subsidies.

While the results from the questionnaire should only be taken as indicative, they should inspire further research towards the development of biogas technologies in the region. In the final subsection, several recommendations are listed based on the results of the questionnaire and the literature review.

7.2 Recommendations

1. **1.** The CEMEREM project and Taita Taveta University are in a great position to work with the local community and should develop community projects or potentially work with local students and organizations to conduct research, training, and outreach programs within the local community.
2. **2.** Local infrastructure and employees should play the largest role in biogas development projects. This has the benefit of reducing the local unemployment levels as well as increasing the local's perceptions of the new technology. First-hand knowledge of how the technology works and understanding how to maintain the system locally will lead to higher dissemination and operability rates.
3. **3.** Potential project leaders should work with local organizations and the local microfinance knowledge base to determine the best funding methods for biogas development. Subsidies should not be a primary driver of biogas dissemination. If they are used, they should be limited and only used to enable those at the lowest income brackets to potentially gain access.
4. **4.** Local organizations and government should work to improve the local knowledge about HAP to increase the welfare of locals. For those households which cannot benefit from biogas, they can still benefit greatly from switching from a low efficiency stove to a higher efficiency stove.
5. **5.** Further research should be conducted in the region to determine the viability, benefits and costs of farmers switching to zero or semi-zero grazing techniques.
6. **6.** Further research should be conducted to better understand the effects of co-digestion of local substrates.
7. **7.** Further research should consider the difficulty of water access. Some regions in Taita Taveta spend several hours to retrieve water, and this would put undue burden on the potential adopter.
8. **8.** Potential project leaders should communicate with local village leaders to reach out to the community. Pilot projects should try and get the village leaders support to increase the chances of dissemination.

References:

1. Adesina, A.A., Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Paso and Guinea, West Africa. *Agricultural Economics.* (13). 1–9.
2. Adoyo, F., Magermans, R., Munchena, F., Ngigi, A., Okello, B., Van der Vleuten, F., & Wilson, L. (2007). Promoting Biogas Systems in Kenya: A Feasibility Study. Biogas for Better Life: An Africa Initiative. Nairobi, Kenya.
3. Baumgartner, J., Schauer, J.J., Ezzati, M., Lu, L., Cheng, C., Patz, J.A. & Bautista, L.E. (2011). Indoor air pollution and blood pressure in adult women living in rural China. *Environmental Health Perspectives.* 119(10). 1390-1395. https://doi.org/10.1289/ehp.1003371
4. Biogas Taita. (2018). About: Our Achievements. Retrieved on 10 April 2018 from: http://biogas-taita.de/about.php
5. Blanchard, R.E & Hamid, R.G. (2018). An Assessment of Biogas as a Domestic Energy Source in Rural Kenya: Developing a Sustainable Business Model. *Renewable Energy.* https://doi.org/10.1016/j.renene.2018.01.032
6. Caceres, E.R. & Chiliquinga, B. (1986). Experiences with rural biodigesters in Latin America. *Biogas Technology, Transfer and Diffusion* (Edited by M. M. EI-Halwagi). 150-165. Elsevier, London and New York.
7. Clancy, J. & Stockbridge, M. (2017) The Gender and Energy Research Programme: What we know so far and considerations. Energy International Secretariat. Hague, Netherlands. Retrieved 20 March 2018 from http://www.energia.org/cm2/wp-content/uploads/2017/03/Policybrief-Energia-March-GERP-2017-final-lr.pdf
8. De Vaus, D.A. (2001). *Research Design in Social Research*. London
9. Dohoo, C., Vanleeuwen, J., Guernsey, J., Critchley, K. & Gibson, M. (2013). Impact of biogas digesters on wood utilization and self-reported back pain for women living on rural Kenyan smallholder dairy farms. *Global public health*. 8. https://doi.org/10.1080/17441692.2012.758299.
10. El-Mashad, H.M. & Zhang, R. (2010). Biogas production from co-digestion of dairy manure and food waste. *Bioresource Technology.* 101(11). 4021–4028. https://doi.org/10.1016/j.biortech.2010.01.027
11. Feleke, S. & Zegeye, T. (2006). Adoption of improved maize varieties in Southern Ethiopia: factors and strategy options. *Food Policy*. 31(5). 442–457. https://doi.org/10.1016/j.foodpol.2005.12.003.
12. FAO. (2011). State of the Worlds Forests 2011. Food and Agriculture Organization of the United Nations. Rome, Italy. Retrieved 15 February 2018 from: http://www.fao.org/docrep/013/i2000e/i2000e00.htm.
13. Garfí, A., Martí-Herrero, J., Garwood, A. & Ferrer, I. (2016). Household anaerobic digesters for biogas production in Latin America: A review. *Renewable and Sustainable Energy Reviews.* 60. 599-614. https://doi.org/10.1016/j.rser.2016.01.071.

14. Gitonga, S. (1997). Biogas Promotion in Kenya: A review of experiences, *Practical Action*. Warwickshire, UK.

15. Heegde, F.T. & Sonder, K. (2007). Domestic Biogas in Africa: A first assessment of the potential and need. Biogas for Better Life: An African Initiative. Retrieved 05 March 2018 from: http://www.snvworld.org/download/publications/biogas_potential_and_need_in_africa.pdf

16. Karki, A.B. (2001). Biogas Support Program and Netherlands Development Organization: Advanced Course in Biogas Technology. Lalitpur, Nepal. Retrieved on 20 May 2018 from: https://www.pseau.org/outils/ouvrages/snv_advanced_course_in_biogas_technology_2001.pdf

17. Khan, A. (2017). German Decentralized Technology for Sustainable Urban & Rural Organic Waste Management. Nagaro GmbH.

18. Kelebe, H.E., Ayimut, K.M., Berhe, G.H. & Hinsta, K. (2017). Determinants for Adoption Decision of Small Scale Biogas Technology by Rural Households in Tigray, Ethiopia. *Energy Economics*. 66. 272-278. 10.1016/j.eneco.2017.06.022.

19. Kenyan Ministry of Energy (2018). Biogas Overview. Nairobi, Kenya. Retrieved 03 March 2018 from: http://energy.go.ke/biogas/

20. Krossman, W., Pönitz, U., Habermehl, S., Hoerz, T., Krämer, P., Klinger, B., ... Krieg, H.E. (1999). Biogas Digest Volume I. Biogas Basics, Information and Advisory Service on Appropriate Technology (ISAT), *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ). Eschborn, Germany. Retrieved on 10 March 2018 from http://biogas.ifas.ufl.edu/ad_development/documents/biogasdigestvol1.pdf

21. Lavrakas, P.J. (2008*). Encyclopedia of survey research methods*. Thousand Oaks, CA: SAGE Publications Ltd. http://dx.doi.org/10.4135/9781412963947

22. Lekule, F.P. (1996). Technologies for improving the wellbeing of rural women in Tanzania. Final report submitted to FAO/SIDA Farming Systems Programme.

23. Lukehurst, C.T., Frost, P. & Al Seadi, T. (2010). Utilisation of digestate from biogas plants as biofertiliser. *IEA bioenergy*, 1-36.

24. Martin W.J. II, Glass R.I., Araj H., Balbus J., Collins F.S., Curtis S., … & Bruce, N.G. (2013). Household Air Pollution in Low- and Middle-Income Countries: Health Risks and Research Priorities. *PLoS Med*. 10(6). http://dx.doi.org/10.1371/journal.pmed.1001455

25. Masawi, V. (2015). County Annual Development Plan 2016/2017. Taita Taveta, Kenya.

26. Msibi, S. & Kornelius, G. (2017). Potential for domestic biogas as household energy supply in South Africa. *Journal of Energy in Southern Africa*. 28(2). 1-13. http://dx.doi.org/10.17159/2413-3051/2017/v28i2a1754

27. Mwesigye, A., Buhwezi, K.B., Arineitwe, J. & Colonna, G. (2011). Challenges to the sustainability of small scale biogas technologies in Uganda. 2nd International Conference on Advances in Engineering and Technology. Entebbe, Uganda.

28. Mwirigi, J., Makenzi, P., & 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. 106-115. https://doi.org/10.1016/j.esd.2009.05.002.

29. Muchiri, L. (2008). Gender and equity in bioenergy access and delivery in Kenya. Retrieved 15 March 2018 from: http://www.energia.org/cm2/wp-content/uploads/2015/06/65-Gender-and-equity-in-bioenergy-access-and-delivery-in-Kenya.pdf

30. Mukumba, P., Makaka, G. & Mamphweli, S. (2016). Anaerobic digestion of donkey dung for biogas production. *South Africa Journal of Science.* 112(7/8). http://dx.doi.org/10.17159/ sajs.2016/20160013

31. Mulinda, C., Hu, Q. & Pan, K. (2013). Dissemination and Problems of African Biogas Technology. *Energy and Power Engineering.* 5(8). 506-512. https://doi.org/10.4236/epe.2013.58055.

32. Ndegwa, G. & Breuer, T. & Hamhaber, J. (2011). Woodfuels in Kenya and Rwanda: powering and driving the economy of the rural areas. *rural21*. 18. 26-30.

33. Ngumah, C., Ogbulie, J., Orji, J. & Amadi, E. (2013). Potential of Organic Waste for Biogas and Biofertilizer Production in Nigeria. *Journal of Environmental Research, Engineering and Management.* 63. 60-66. https://doi.org/10.5755/j01.erem.63.1.2912.

34. Ni, J. & Nyns, E. (1993). Biomethanation - A Developing Technology in Latin America.

35. Ni, J. & Nyns, E. (1996). New concept for the evaluation of rural biogas management in developing countries. *Energy Conversion and Management.* 37. 1525–1534. https://doi.org/10.1016/0196-8904(95)00354-1.

36. Nyamu, G. (2014). Kenya Domestic Biogas User Survey 2014. Kenya National Domestic Biogas Program. Kenya. Retrieved 15 March 2018 from: http://www.snv.org/public/cms/sites/default/files/explore/download/biogas_users_kpt_survey_-_kenya_final_report_oct_2014.pdf

37. Okumu, B. & Muchapondwa, E. (2017). Economic Valuation of Forest Ecosystem Services in Kenya: Implication for Design of PES Schemes and Participatory Forest Management. Working Papers 693. Economic Research Southern Africa. Retrieved 20 March 2018 from: https://econrsa.org/node/1404

38. Omer, A.M. & Fadalla, Y. (2003). Biogas energy technology in Sudan. *Renewable Energy*. 28. 499-507. https://doi.org/10.1016/S0960-1481(02)00053-8.

39. Patel, A., Meleth, S., Pasha, O., Goudar, S., Esamai, F., Garces, A.L., … & Hibberd, P. (2015). Impact of exposure to cooking fuels on stillbirths, perinatal, very early and late neonatal mortality - a multicenter prospective cohort study in rural

communities in India, Pakistan, Kenya, Zambia and Guatemala. *Maternal Health, Neonatology and Perinatology.* 1(18). 10.1186/s40748-015-0019-0.

40. Porras, I., Vorley, B. & Amrein, A. (2015). The Kenya National Domestic Biogas Programme: can carbon financing promote sustainable agriculture? IIED and Hivos. Retrieved 10 April 2018 from: https://hivos.org/sites/default/files/publications/pes_and_the_kenya_national_domestic_biogas_programme.pdf

41. Republic of Kenya (2004). Sessional Paper No.4 of 2004 on Energy. Government Printer, Nairobi.

42. Roopnarain, A. & Adeleke, R. (2017). Current Status, hurdles and future prospects of biogas digestion technology in Africa. *Renewable and Sustainable Energy Reviews.* 67. 1162-1179. http://dx.doi.org/10.1016/j.rser.2016.09.087

43. Singh, K.J. & Sooch, S. (2004). Comparative study of economics of different models of family size biogas plants for state of Punjab, India. *Energy Conversion and Management.* 45. 1329-1341. https://doi.org/10.1016/j.enconman.2003.09.018.

44. Smith, K. R., Bruce, N., Balakrishnan, K., Adair-Rohani, H., Balmes, J., Chafe, Z., … Rehfuess, E. (2014). Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annual Review of Public Health.* 35. 185-206. https://doi.org/10.1146/ annurev-publhealth-032013-182356

45. Sovacool, B., Kryman, M. & Smith, T. (2014). Scaling and commercializing mobile biogas systems in Kenya: A qualitative pilot study. *Renewable Energy*. 76. https://doi.org/10.1016/j.renene.2014.10.070.

46. Subedi, M., Matthews, R., Pogson, M., Abegaz, A., Balana, B., Oyesiku-Blakemore, J. & Smith, J. (2014). Can biogas digesters help to reduce deforestation in Africa? *Biomass and Bioenergy*. 70. 1-12. https://doi.org/10.1016/j.biombioe.2014.02.029.

47. Sun, D., Bai, J., Qiu, H. & Cai, Y. (2014). Impact of government subsidies on household biogas use in rural China. *Energy Policy.* 73. 748-756. https://doi.org/10.1016/j.enpol.2014.06.009.

48. TTCG (2013). The First Taita Taveta County Integrated Development Plan 2013-2017. Taita Taveta Kenya.

49. Tatlidil, F., Bayramoglu, Z. & Akturk., D. (2009). Animal Manure as One of the Main Biogas Production Resources: Case of Turkey. *Journal of Animal and Veterinary Advances*. 8(2). 2473-2476.

50. Templeton, R.M. & Bond, T. (2011). History and future of domestic biogas plants in the developing world. *Energy for Sustainable Development.* 15. 347–354. https://doi.org/10.1016/j.esd.2011.09.003.

51. United Nations Foundation (2012). Global Alliance for Clean Cookstoves. Retrieved 30 February 2018 from: http://cleancookstoves.org/.

52. United Nations (2017). Household Size and Composition Around the World. United Nations Department of Economic and Social Affairs, Population Division. Retrieved 20 April 2018 from: http://www.un.org/en/development/desa/population/publications/pdf/popfacts/PopFacts_2017-2.pdf

53. United Nations (2018). *Kenya Statistics.* United Nations Children's Fund, Retrieved 15 April 2018 from: https://www.unicef.org/infobycountry/kenya_statistics.html

54. University of Southern California. (2018) *Organizing Your Social Sciences Research Paper: Types of Research Designs.* Retrieved 28 May 2018 from http://libguides.usc.edu/writingguide/researchdesigns

55. Wise, D., Leuschner, A., Levy, P. & Sharaf, M. (1986). A practical village biogas system for wastes and agricultural residues, *Resources and Conservation*. 13(1). 23-36. https://doi.org/10.1016/0166-3097(86)90004-0

56. World Energy Conference. (1989). Technology of Biogas Production and Applications in Rural Areas. London, United Kingdom. Retrieved 20 February 2018 from: http://www.energyhimalaya.com/directories/books-and-articles/biogas/ae897e04.pdf

57. World Health Organization (2012). Burden of Disease from Household Air Pollution for 2012. Geneva, Switzerland. Retrieved 28 February 2018 from: http://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf

58. World Health Organization (2015). The Global Health Observatory. Geneva, Switzerland. Retrieved 28 February 2018 from http://www.who.int/gho/en/

59. World Health Organization. (2016). Preventing Disease through Healthy Environments. Geneva, Switzerland. Retrieved 28 February 2018 from: http://www.who.int/quantifying_ehimpacts/publications/preventing-disease/en/

60. World Health Organization (2018). Household Air Pollution. Global Health Observatory Data. Geneva, Switzerland. Retrieved 28 February 2018 from: http://www.who.int/gho/phe/indoor_air_pollution/en/

61. Zhu, D. (2010). *Co-digestion of Different Wastes for Enhanced Methane Production.* (Dissertation). Retrieved on 15 May 2018 from: https://etd.ohiolink.edu/

Appendix I: Additional Documentation

1. Biogas Questionnaire

Taita Taveta Biogas Questionnaire

CEMEREM* PROJECT IN COLLABORATION WITH TAITA TAVETA UNIVERSITY AND FREIBERG UNIVERSITY OF MINING AND TECHNOLOGY

Thank you very much for agreeing to participate in this questionnaire about biogas potential and opportunities in Taita Taveta. This questionnaire is a part of a biogas pilot project with the TTU that will install 4 Smart Biogas plants and provide us with valuable information that can lead to positive environmental and economic changes in the county. The questionnaire will take approximately 10 to 15 minutes of your time.

*CEMEREM: Center for Mining, Environmental Engineering and Resource Management

the information given will be treated as confidential and will be used for the purported research only

Date:	
Subcounty:	
Ward:	
Coordinates:	
Survey Number:	
Translator:	

Please select only one answer unless otherwise noted.

Land Usage

1. ***How many hectares is the land available for you to use?***
☐0-0.49 ha ☐0.5-0.99 ha ☐1-4.99 ha ☐5-9.99 ha ☐10+ ha

2. ***Do you plant crops?***
☐No (Please move on to next question ☐Yes (Please check all types below)

O **Maize**	O **Potatoes**	O **Bananas**	O **Pigeon Peas**	O **Sugar Cane**
O **Cabbage**	O **Avocados**	O **Carrots**	O **Cow Peas**	O **Napier Grass**
O **Beans**	O **Kale**	O **French beans**	O **Green Grams**	O **Other**............................

3. ***Do you have livestock?***
☐No (Please move on to next question ☐Yes (please check all types and add quantities below)

	O **Cows**	O **Goats**	O **Sheep**	O **Chickens**	O **Donkeys**	O **Other**..........................
Quantity						

Energy Usage

4. ***For what purposes do you use energy, and what type of energy do you use for each purpose?***
(Please match the energy usage with the type of fuel you use. You can check multiple.)

	Wood	**Charcoal**	**Gas**	**Electricity**	**Biogas**	**Other:** ....
Heating	O	O	O	O	O	O
Cooking	O	O	O	O	O	O
Lighting	O	O	O	O	O	O
Preserving	O	O	O	O	O	O
Electronics	O	O	O	O	O	O
Commercial usage	O	O	O	O	O	O

5. ***Approximately how much money do you spend each month on each type of energy?*** (You can fill out multiple)

	Wood	**Charcoal**	**Gas**	**Electricity**	**Biogas**	**Other:**................................
Shillings/month						

6. ***Do you have access to electricity?***
☐No, but I would use electricity if I had access.
☐No, and electricity is too expensive to use anyway.
☐Yes, and I use it.
☐Yes, but it is too expensive to use.
☐Other..

7. ***Do you collect firewood?***

☐No (Please move on to next question) ☐Yes (Please answer 7a-c)

a. ***Adding together all household labor, for how many hours a week is firewood collected?***

☐Less than 1 hour ☐1-3 hours ☐3-5 hours ☐5-10 hours ☐10+ hours

b. ***What is the age and gender of those who collect firewood?*** (You can check multiple)

	0 – 12 years old	13 – 18 years old	19- 64 years olds	65+ years old
Male	○	○	○	○
Female	○	○	○	○

c. ***What do you do with the leftover ash?***

☐Dispose ☐Compost ☐Toilet Maintenance ☐Other..

Opinions

8. ***Are you aware about damage to forests due to firewood collection?***

☐No
☐Yes, and I am not at all concerned
☐Yes, and I am not very concerned
☐Yes, and I am concerned
☐Yes, and I am very concerned

9. ***Are you aware of health problems related to wood cooking stoves?***

☐No
☐Yes, and I am not at all concerned
☐Yes, and I am not very concerned
☐Yes, and I am concerned
☐Yes, and I am very concerned

10. ***Do you think women and men bare equal burden when it comes to wood collection?***

☐No, women bare more burden and that is okay
☐No, women bare more burden and that is a problem
☐No, men bare more burden and that is okay
☐No, men bare more burden and that is a problem
☐Yes

11. ***Do you make an effort to mitigate damage to forests?***

☐No, I do not think about damage to forests
☐No, I do not have time or energy to consider it
☐I try to make small changes to lower damage to forests
☐I have made large lifestyle changes to lower damage to forests

12. ***Do you make an effort to mitigate health risks from cooking stoves?***

☐No, I do not think about it
☐No, I do not have time or energy to consider it
☐I try to make small changes to lower health risks from wood smoke
☐I have made large lifestyle changes to lower health risks from wood smoke

Biogas Potential

13. *What kind of organic waste do you have on a daily basis, and how much do you have?* (Check all that apply, check volume for each variety selected)

Type	Volume				
☐**Kitchen Scraps**	○Less than ¼ bucket	○¼ -½ bucket	○½-1 bucket	○1-2 buckets	○2+ buckets
☐**Garden Scraps**	○Less than ¼ bucket	○¼ -½ bucket	○½-1 bucket	○1-2 buckets	○2+ buckets
☐**Used Oil**	○Less than ½ a cup	○½ -1 cup	○1-2 cups	○2-5 cups	○5+ cups

14. *What do you do with leftover organic waste?*
☐Dispose of it ☐Burn it ☐Compost ☐Animal Feed

15. *Do you collect animal dung?*
☐ No ☐Yes, I use it as fertilizer ☐Yes, I sell it

16. *Before this questionnaire, were you aware about biogas systems?*
☐No (Please move on to next question)
☐Yes, and I have a neutral opinion about biogas. (Please answer 16a-e)
☐Yes, and I have a negative opinion about biogas. (Please answer 16a-e)
☐ Yes, and I have a positive opinion about biogas. (Please answer 16a-e)

a. *When did you learn about biogas?*
☐1960-1980 ☐ 1981-1990 ☐ 1991-2000 ☐ 2001-2010 ☐2011-2017 ☐Can't recall

b. *How did you learn about biogas?*
☐Neighbors ☐Friends ☐NGO ☐Government Agencies ☐Local company ☐TV/Internet
☐Taita Taveta University ☐Primary/Secondary Education ☐Other..

c. *How expensive do you think a biogas system costs with installation?*
☐10,000-14,999 Shillings ☐ 15,000-24,999 Shillings ☐ 25,000-49,999 Shillings
☐ 50,000-99,999 Shillings ☐ 100,000-149,999 Shillings ☐ 150,000+ Shillings ☐No idea

d. *How big of a family do you think a biogas system supports?*
☐1-2 members ☐3-5 members ☐6-10 members ☐11+ members ☐No idea

e. *Were you aware that some biogas systems can use non-animal organic waste as well as animal dung?*
☐No ☐Yes

17. *Following installation of the smart biogas plants at the TTU, do you want to see the biogas plant in operation?*
☐No ☐Yes

18. *Following a successful pilot project, would you support an innovative energy group of community members to be trained to build, install, operate and manage biogas plants?*
☐ Absolutely ☐ Maybe ☐ Not sure ☐ Maybe later ☐No, not a good proposal

19. *If the group from question 18 was formed, would you like to be a member of this group?*
☐ Absolutely ☐ Maybe ☐ Not sure ☐ Maybe later ☐No, not a good proposal

20. ***A Nagaro Smart Biogas plant can process approximately 10 kg of organic product per day. Does your family have enough organic waste available to feed the biogas plant?***
☐ Every day ☐ Most days ☐ Some days ☐ Occasionally ☐No, very unlikely ☐ No

21. ***If you are not able to alone, do you have nearby neighbors with whom you could collectively produce 10 kg of organic waste per day?***
☐ Every day ☐ Most days ☐ Some days ☐ Occasionally ☐No, very unlikely ☐ No

22. ***Assuming you wanted to install and operate a biogas plant for your family, how much money could you set aside every month to pay off the biogas plant?***
☐ 0-49 Shillings ☐ 50-199 Shillings ☐200-499 Shillings ☐ 500-999 Shillings
☐1,000-2,499 shillings ☐2,500+ shillings

23. ***Following a successful pilot project, would you be willing to recommend funding for smart biogas plants from the county government?***
☐Yes, it is extremely important ☐Yes, but it's not a big priority ☐Not sure ☐No

24. ***Do you have access to land where you could install a Smart biogas plant with access to sunlight?*** *($2m^2$)*
☐No ☐Yes

Personal Information

25. ***How many people live in your household?***
☐One ☐Two ☐Three ☐Four ☐Five ☐Six or more ☐Abstain

26. ***What is your marital status?***
☐Single ☐Married ☐Separated ☐Divorced ☐Widowed ☐Abstain

27. ***What is your gender?***
☐Male ☐Female ☐Abstain

28. ***What is your age?***
☐15-25 ☐26-35 ☐36-45 ☐46-55 ☐56-65 ☐66+ ☐Abstain

29. ***Profession***
☐farmer ☐business owner........................ ☐Unemployed ☐Other........................ ☐Abstain

30. ***What is your highest level of education obtained?***
☐Primary Education ☐Secondary Education ☐Vocational Training ☐University ☐Post-Graduate

31. ***Estimated monthly Income for the household?***
☐0-99 ☐100-499 ☐500-1,499 ☐1,500-4,999 ☐5,000-19,999 ☐20,000+ ☐Abstain

32. ***Do you have a title deed for your land?***
☐ Yes, I have a deed ☐ No, I have no deed

33. ***Community Involvement***

....

....

34. ***Contact Information***

....

....

End of Questionnaire - Thank you for participating in the survey!

Additional Personal Comments

2. Education, Age, Gender opinion question responses

Are you aware about damage to forests due to firewood collection?

		No	Yes, and I am not at all concerned	Yes, and I am not very concerned	Yes, and I am concerned	Yes, and I am very concerned	Total Respondents
Education	Illiterate	0.0%	6.3%	0.0%	87.5%	6.3%	16
	Primary Education	6.3%	7.3%	5.2%	72.9%	8.3%	96
	Secondary Education	4.8%	1.6%	15.9%	63.5%	14.3%	63
	Vocational Training	0.0%	0.0%	13.6%	45.5%	40.9%	22
	University	0.0%	0.0%	33.3%	33.3%	33.3%	3
Age	15-25	0.0%	6.1%	18.2%	66.7%	9.1%	33
	26-35	7.9%	10.5%	5.3%	63.2%	13.2%	38
	36-45	2.6%	5.3%	15.8%	68.4%	7.9%	38
	46-55	5.0%	2.5%	7.5%	65.0%	20.0%	40
	56-65	3.8%	0.0%	0.0%	69.2%	26.9%	26
	66+	8.3%	0.0%	8.3%	75.0%	8.3%	24
Gender	Female	3.5%	4.4%	9.7%	73.5%	8.8%	113
	Male	5.7%	4.6%	9.2%	59.8%	20.7%	87

Are you aware of health problems related to wood cooking stoves?

		No	Yes, and I am not at all concerned	Yes, and I am not very concerned	Yes, and I am concerned	Yes, and I am very concerned	Total Respondents
Education	Illiterate	25.00%	0.00%	12.50%	62.50%	0.00%	16
	Primary Education	43.75%	3.13%	7.29%	40.63%	5.21%	96
	Secondary Education	20.63%	1.59%	4.76%	50.79%	22.22%	63
	Vocational Training	9.09%	9.09%	0.00%	45.45%	36.36%	22
	University	33.33%	0.00%	33.33%	33.33%	0.00%	3
Age	15-25	21.21%	6.06%	9.09%	51.52%	12.12%	33
	26-35	31.58%	5.26%	2.63%	52.63%	7.89%	38
	36-45	31.58%	0.00%	7.89%	47.37%	13.16%	38
	46-55	25.00%	5.00%	5.00%	40.00%	25.00%	40
	56-65	46.15%	0.00%	7.69%	34.62%	11.54%	26
	66+	37.50%	0.00%	8.33%	45.83%	8.33%	24
Gender	Female	30.09%	2.65%	6.19%	49.56%	11.50%	113
	Male	32.18%	3.45%	6.90%	41.38%	16.09%	87

Do you think women and men bare equal burden when it comes to wood collection?

		No, women bare more burden and that is okay	No, women bare more burden and that is a problem	Yes	No, men bare more burden and that is a problem	No, men bare more burden and that is okay	Total Respondents
Education	Illiterate	50.00%	6.25%	43.75%	0.00%	0.00%	16
	Primary Education	38.54%	5.21%	48.96%	4.17%	2.08%	95
	Secondary Education	25.40%	3.17%	65.08%	4.76%	1.59%	63
	Vocational Training	22.73%	18.18%	54.55%	0.00%	4.55%	22
	University	66.67%	33.33%	0.00%	0.00%	0.00%	3
Age	15-25	33.33%	6.06%	57.58%	3.03%	0.00%	33
	26-35	42.11%	13.16%	39.47%	5.26%	0.00%	38
	36-45	26.32%	2.63%	71.05%	0.00%	0.00%	38
	46-55	35.90%	5.13%	48.72%	5.13%	5.13%	40
	56-65	38.46%	3.85%	46.15%	3.85%	7.69%	26
	66+	25.00%	8.33%	62.50%	4.17%	0.00%	24
Gender	Female	39.82%	7.96%	45.13%	4.42%	2.65%	113
	Male	26.74%	4.65%	65.12%	2.33%	1.16%	87

Do you make an effort to mitigate damage to forests?

		No, I do not think about damage to forests	No, I do not have time or energy to consider it	I try to make small changes to lower damage to forests	I have made large lifestyle changes to lower damage to forests	Total Respondents
Education	Illiterate	18.75%	6.25%	75.00%	0.00%	16
	Primary Education	16.67%	1.04%	76.04%	6.25%	96
	Secondary Education	22.22%	4.76%	57.14%	15.87%	63
	Vocational Training	22.73%	0.00%	45.45%	31.82%	22
	University	0.00%	0.00%	66.67%	33.33%	3
Age	15-25	27.27%	3.03%	60.61%	9.09%	33
	26-35	18.42%	5.26%	65.79%	10.53%	38
	36-45	18.42%	5.26%	68.42%	7.89%	38
	46-55	17.50%	0.00%	65.00%	17.50%	40
	56-65	15.38%	0.00%	73.08%	11.54%	26
	66+	16.67%	0.00%	66.67%	16.67%	24
Gender	Female	23.01%	2.65%	66.37%	7.96%	113
	Male	13.79%	2.30%	66.67%	17.24%	87

Do you make an effort to mitigate health risks from cooking stoves?

		No, I do not have time or energy to consider it	No, I do not think about it	I try to make small changes to lower health risks from wood smoke	I have made large lifestyle changes to lower health isks from wood smoke	Total Respondents
Education	Illiterate	0.00%	31.25%	68.75%	0.00%	16
	Primary Education	1.04%	43.75%	47.92%	7.29%	96
	Secondary Education	1.59%	39.68%	38.10%	20.63%	63
	Vocational Training	0.00%	9.09%	59.09%	31.82%	22
	University	0.00%	33.33%	66.67%	0.00%	3
Age	15-25	0.00%	36.36%	57.58%	6.06%	33
	26-35	0.00%	39.47%	47.37%	13.16%	38
	36-45	2.63%	36.84%	47.37%	13.16%	38
	46-55	2.50%	32.50%	47.50%	17.50%	40
	56-65	0.00%	42.31%	42.31%	15.38%	26
	66+	0.00%	41.67%	41.67%	16.67%	24
Gender	Female	0.88%	38.05%	50.44%	10.62%	113
	Male	1.15%	36.78%	44.83%	17.24%	87