BIOGAS AND ITS POTENTIAL IN THE LOCAL COMMUNITIES: CASE STUDY OF WARR SUB-COUNTY, ZOMBO DISTRICT WEST NILE UGANDA

BY

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A RESEARCH REPORT SUBMITTED TO THE COLLEGE OF APPLIED SCIENCES AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR AN AWARD OF DEGREE IN BACHELOR OF SCIENCE IN ENVIRONMENTAL MANAGEMENT OF KAMPALA INTERNATIONAL UNIVERSITY

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DECLARATION

I hereby declare that this research material is entirely my work, does not breach any law of copyright and that it has never been submitted to any academic institution for any academic award whatsoever.

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APPROVAL

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(SUPERVISOR)

DEDICATION

In Evergreen Loving Memory of my Dearly Beloved Brother, Biantalo Steven; you're a Rare Gem gone too soon, I will never forget your esteem love and care you nurtured me, I really dearly miss you very much. May your Gentle Soul Continue to Rest in Perfect Eternal Peace in Bosom of the Lord, Amen Affoyo.

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Special thanks are also extended to my dad Mr. Nazareno Uneggiu and My Mum Mss. Christine Abom, My brothers; Gonzales, Deo. Julius, Joseph, and Disu, not forgetting Late Biantalo Steven; may your soul rest in Eternal Peach with Jesus Christ. Amen. My sisters rose Afoyorwòth, Akumu, Prisca Lillian, Maryline and Cleir.

Really very big thanks to you Sister Biwinjire Irene for educating me

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ABBREVIATIONS

ABPP	Africa Biogas Partnership Programmed
ADRA	Adventist Development and Relief Agency
AEATREC	Agricultural Engineering and Appropriate Technology Research Center
AFIEGO	Africa Institute for Energy Governance
AMFIU	Association of Microfinance Institutions of Uganda
BAM	Biogas Appliance Manufacturers
BCE	Biogas Construction Enterprises
C:N	Carbon to Nitrogen Ratio
BHP-HOUR	Biogas per Household per Hour
CAMARTEC	Centre for Agricultural Mechanization and Appropriate Technology
CBO	Community Based Organization
EAETDN	East African Energy Technology Development Network
ERT	Energy for Rural Transformation
GEEREF	Global Energy Efficiency and Renewable Energy Fund
HPIU	Heifer Project International Uganda
HIVOS	Humanist Institute for International Development Cooperation
M&E	Monitoring and Evaluation
MDGs	Millennium Development Goals
MEMD	Ministry of Energy and Mineral Development
MFI	Micro Finance Institution
NAADS	National Agriculture Advisory Services
NBSC	National Biogas Steering Committee
NDP	National Development Plan
NGO	Non Governmental Organization
PEAP	Poverty Eradication Action Plan
PFI	Participating Financial Institutions
PHC	Primary Health Care
PID	Programme Implementation Document
PMA	Plan for modernization of Agriculture
PPP	Public Private Partnership

PSFU	Private Sector Foundation Uganda
R&D	Research and Development
SACCO	Savings and Credit Cooperative Society
SDIP	Social Development Sector Strategic Investment Plan
SME	Small and Medium Enterprise
SNV	Netherlands Development Organization
TA	Technical Assistance
TOT	Training of Trainer
UBA	Uganda Biogas Association
UDBP	Uganda Domestic Biogas programme
UDBPO	Uganda Domestic Biogas Program Office
UECCC	Uganda Energy Credit Capitalization Company
UML	Uganda Microfinance Limited
UNBS	Uganda National Bureau of Standards
UNDBPO	Uganda National Domestic Biogas Programme Office
UNDP	United Nations Development Programme
UPE	Universal Primary Education
VTI	Vocational Training Institute

ABSTRACT

Accelerated population growth and emerging alternate use for energy has threatened the world energy supply resulting in the thirst for alternative energy. One of such alternative source of energy is the use of Biogas. This study examined the potential of biogas usage by rural community in Warr Sub County, Zombo district, by first examining the energy situations and then assessing the biogas feasibility indicators and the technical potential of biogas usage in the area.

The research design was exploratory which was achieved by use of a single qualitative method of triangulation which involved the use of questionnaires, interviews, administrative and other sources such as journals, internet resources and text books in libraries.

The findings confirmed that the available sources of energy is wood fuel (firewood) which is mostly used by over 95.5% of the households, followed by cow dung, crop residue and paraffin.

The feasibility indicators showed biogas has never been used in area before and there was limited knowledge about it, majority (70%) had positive attitude, and there is ideal environmental factors (temperature and topography) for digester constructions. The social-economic situation was a major limiting factor due to very low income level.

The assessment of the technical potential revealed that the raw material such as animal waste and water was available for majority households. The average number of cows per household was found to be 5, and the quantity of dung per cow was experimentally estimated to be 10Kg per day. The average number of people per household was 7.

However the success of a biogas plant in the rural areas would depend on the selection of the plant design, size, site, materials of construction, type of plant, method of construction and acceptability as discuss in the findings.

CHAPTER ONE

1.0 Introduction

This chapter covers the background to the study, the problem statement, purpose of the study, research objectives, research questions, significance of the study and the conceptual framework.

1.1Background to study

This study seeks to evaluate the technical potential for biogas usage in rural areas of Zombo district in West Nile, Uganda by first examining the energy situation in the area. Energy has now become a very common word that cuts across all fields of study. Accelerated population growth and emerging alternate use for energy has threatened the world energy supply resulting in the thirst for alternative energy. In the rural areas of Uganda the main fuel for fire is firewood which is basically dried tree stems, branches and twigs (Anthony et al, 2009). Women do the cooking and to start a fire they need to walk several kilometers in search of wood before coming to the actual cooking. Other duties such as household chores childcare and farm work must also be attended to; this entire work load makes life very unbearable for the women. Having an alternative fuel can therefore change the lives of the women in more ways than one in addition to increasing the time they have to attend to other social economic activities. The burning of firewood produces large quantities of carbon dioxide which causes a lot of respiratory problems to rural women each year (Zeleke 2008). The carbon dioxide produced from the burning fuel wood has no sink to absorb it because the forests which are cut to make the firewood are not given enough time to rejuvenate. The use of firewood contributes to global warming hence the need for a better alternative (Reardon &Vosti 1995). The very popular alternative energy sources are wind, nuclear, solar and not so popular biogas energy. The alternative energy sources are used to supplement the most common energy source which is fossil fuel however they are not without their own disadvantages.

Biogas may not be new in other parts of the world like China and India, but in Uganda it is – especially among small scale farmers in rural districts like Zombo. In Uganda more than 90 percent of people's energy needs are met with biomass (Julian, 2013): Over 60 percent of total wood production is used for fuel wood. This has led to indiscriminate tree felling and there is therefore a need to promote other energy sources like biogas, especially for use at household level. Biogas is seen as a good alternative source of energy for cooking and lighting. It is also a way to make use of animal manure, thereby improving the sanitation of the homestead and providing fertilizer. Biogas also helps improve the health of women involved in cooking because it is smokeless. It saves time that would otherwise be spent collecting scarce fuel wood and it saves money that would have been used to buy fertilizers.

1.2 Problem Statement

Firewood is the most significant source of energy in Uganda, and the majority of the people employ it for domestic use and small-scale industries such as brick and tile making, agro-processing (sugar, tea, tobacco), jaggeries, bakery and fish processing (Population and Housing Census, 2002; Tabuti et al., 2003; Yikii et al., 2006). Rural communities especially the women living in Warr Sub County, Zombo district have always had hard time meeting their fuel needs. They spend much time looking for firewood in the forests, bushes, shrubs and swamps, leaving very little time to attend to other social economic activities. Besides the activity of using fuel wood has been the main cause of depletion of forest reserves acerbating the problem of climate change. At present, demand/consumption for firewood in Uganda is estimated to be growing at a rate of 2.5% per annum. According to the Food and Agriculture Organization estimates for Uganda, firewood consumption grew by more than 2 billion tons between the years 1993 and 1997 (FAO, 1999; Tabuti et al., 2003). This growing demand is attributed to an increasing population, a growing industrial sector, as well as the increased rate of urbanisation and high household incomes (NEMA, 1988; Tabuti et al., 2003). Biogas as a fuel alternative has so many advantages to offer the rural people in Uganda. This study, therefore intend to explore the feasibility and the technical potential of biogas usage and its related livelihood improvement for rural women in Warr Sub County, Zombo district.

1.3 Objectives of the Study

1.3.1 General Objective

To examine the potential of biogas usage by rural community in Warr Sub County, Zombo district

1.3.2 Specific Objectives

a) To examine the energy situation in the communities of Warr Sub County, Zombo district
b) To assess the biogas feasibility indicators in the rural communities of Warr Sub County, Zombo district

c) To assess the technical potential of biogas system in the rural communities of Warr Sub County, Zombo district

1.4 Research Questions

The research was guided by the following questions

a) What is the energy situation in the communities of Warr Sub County, Zombo district?
b) What indicators are on the ground that makes biogas technology urgently needed in Warr Sub County, Zombo district?
c) How many household of Warr Sub County, Zombo district can meet the technical requirement for biogas usage?

1.5. Scope of the Study

1.5.1Geographical scope

This study was conducted in Warr sub county Zombo district in West Nile Uganda. Warr Sub County extends over 125 square kilometers, consisting mainly of 2 parishes. War Sub County is one of the seven sub counties of Zombo district. Poverty level is still very high in this region and according to Uganda Bureau of Statistics, Zombo district had a total population of 169,000 in 2012, and area covered is 897.6Km2.

1.5.2. Content scope

The primary area of concern in this study was focused on; the energy situation in the community, the biogas feasibility indicators as seen in energy needs, health and sanitation and the environmental aspect, and animal keeping factors in the area. This helped me to calculate the technical potential to biogas usage in the Warr sub county and made appropriate conclusion.

1.5.3 Time scope

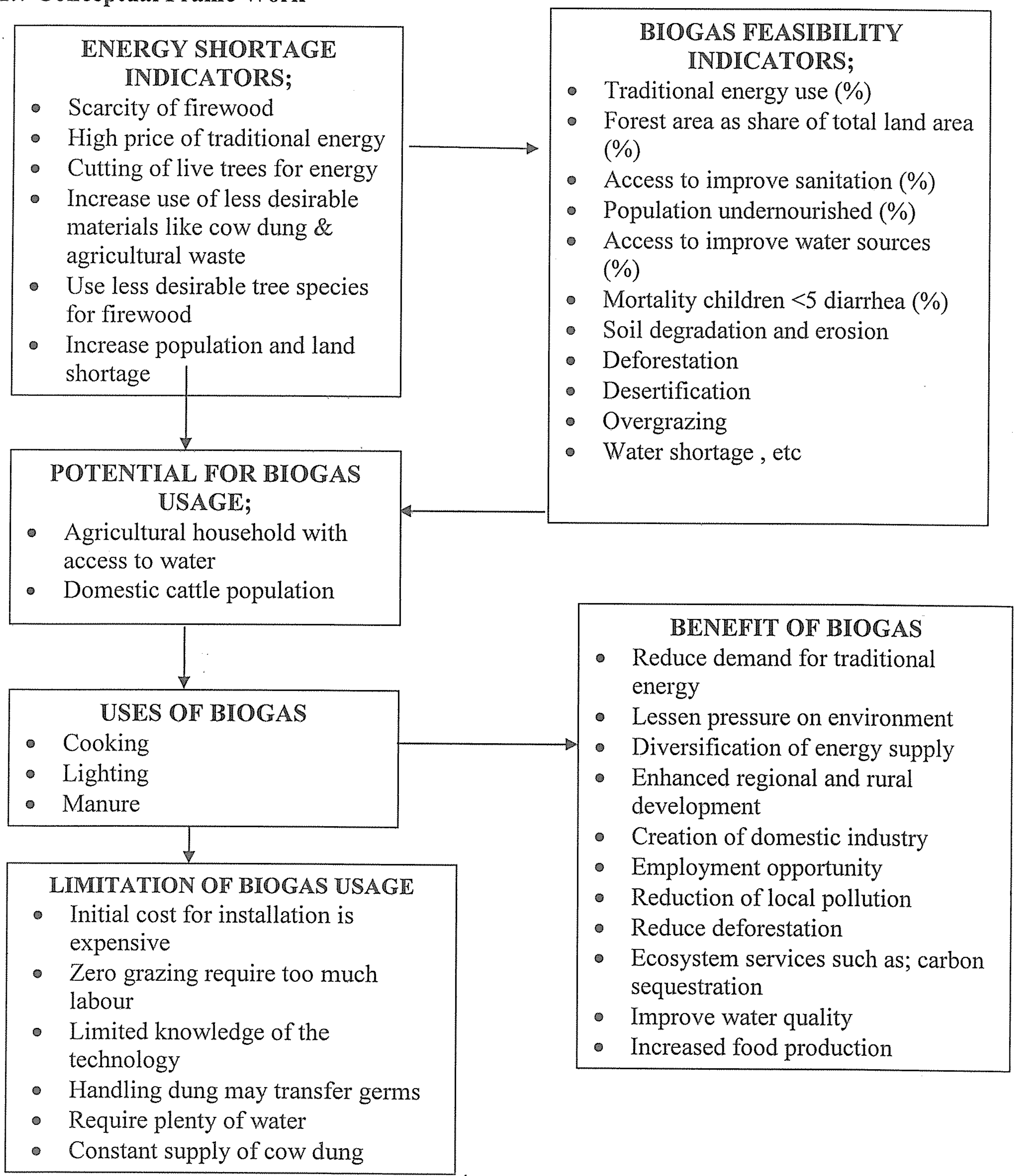
This research took place between June and July 2015.

1.6 Significance of the research

This study was relevant because it is bringing up some of the problems rural people are facing as a result of increased energy scarcity due to population increase.

Secondly it would help to know the way forward in terms of biogas dissemination to rural communities in Uganda. This is very important because most rural households cannot afford electricity even if they are put on the national electric grid. However biogas can serve as alternative energy source for them. Using biogas also has the potential to improve their standard of living both financially and emotionally. Time spent collecting firewood can then be spent on children or on economic activities thus leading to increased income.

1.7 Conceptual Frame Work



CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature sources relating to the objectives of the study that is;-

(i) To examine the energy situation in the communities of Warr Sub County, Zombo district

(ii) To assess the biogas feasibility indicators in the rural communities of Warr Sub County, Zombo district

(iii) To assess the technical potential of biogas system in the rural communities of Warr Sub County, Zombo district

The literature was collected from journals, books, articles, publications among other secondary sources of data.

2.1 Biogas Systems

A biogas plant converts biodegradable waste to a useable gas under anaerobic conditions. This gas consists mainly of methane and carbon dioxide. Material is added to the digester where under anaerobic conditions bacteria convert the material to two products, biogas and slurry. The system consists of a digester, which provides an area for the material to be digested by bacteria in an environment devoid of oxygen. Material is added to the system via an inlet tube and the digested material is then removed from a separate opening (Ochuegu 2010).

"Domestically, biogas can be used for cooking, lighting, heating water, running refrigerators, water pumps and electric generators. Agriculturally, it can be used on farms for drying crops, pumping water for irrigation and other purposes. In industry, it can be used in small-scale industrial operations for direct heating applications such as scalding tanks, drying rooms and in the running of internal combustion engines for shaft power needs" (Akinbami et al, 2001). The slurry is used as a fertilizer and soil composition improver. By treating the material in such a way it not only reduces the pollution of the surrounding area by animal waste but also reduces the need for chemical fertilizers. "Biogas is a service that is broader than just energy supply and a latrine. It uplifts the dignity of women and improves the health and hygienic conditions of families" (Van Nes, and Nhete, 2007). The women are uplifted because their time can be better used for income generating activities, education, and managing the household instead of spending hours collecting firewood.

2.2. Anaerobic Process

An anaerobic process occurs in an environment that lacks oxygen; the organic material (such as carbohydrates, lipids and proteins but not lignin and other hydrocarbons) is broken down in three stages: hydrolysis, acidification and methanization. Hydrolysis is the rate limiting step; it turns the insoluble materials into liquids. Hydrolysis is followed by acidification where the now soluble organic matter is converted into carbon dioxide and short chain organic acids. The final step is methanization, where methane is produced by methanogens. The final gaseous product is composed of 55-75% methane, 25-45% carbon dioxide, and trace amounts of hydrogen sulfide, nitrogen, hydrogen, carbon monoxide, water vapor and oxygen gases (Igoni, 2007, Burke, 2001, Miron, 2000).

2.3 Environment and Development in Uganda

2.3.1 Energy issues

Uganda's total energy consumption consists primarily of biomass (92%), while electricity only constitutes 1.1 % of all energy used (MEMD, 2008). A share of 95.6% of all households uses firewood as their main source of cooking, 26.6 % uses charcoal to prepare their meals (Kabuhire, 2010). Wood as a source of energy has traditionally been cheap or even freely available, but in many parts of Uganda it is increasingly scarce. In Uganda 91% of the population has no access to electricity. This figure is even higher for rural areas, where only 3 % of the people have access to electricity (Pandey et al., 2007). Most rural households therefore choose to use kerosene for lighting instead.

Uganda increasingly has energy problems. The slowly growing electricity network suffers from frequent blackouts, reflecting the serious electricity shortages in the country. The prices of petroleum are rising, and as fuel for transport is rising, the prices for firewood and charcoal are going up as well. Because of Uganda's high population growth and rising incomes over the last two decades of relative political stability, the energy consumption has grown as well. For example, between 1996 and 2008, the amount of charcoal consumed more than doubled from 418,000 to 841,000 tons (MEMD, 2008). This combination of a fast-growing energy demand, decreasing natural resources and high fuel prices has recently caused a period of political instability, in which supporters of the main opposition party protested and rioted on the streets of Uganda's capital Kampala, blaming the government for the steep increases in fuel prices (Economist, 2011).

2.3.2 Environmental problems

While the demand for energy is rising, more wood is used than could be sustainably extracted from Uganda's forests. Deforestation has a long history in Uganda: between 1890 and 1995 the forest cover reduced from 35% to 16% of the land's surface (Kayanya and Byarugaba, 2001). Between 1990 and 2010, the forest cover further decreased with 37.1 %, which translates in an average forest loss of 88,150 ha each year (FAO, 2010) Where Uganda's deforestation rate circles around 2 % each year, most other East African countries have rates that lie below 1 % (Obua et al., 2010). It is estimated that by 2025 all forest on private lands will be deforested (Uganda Forest Department, 2003).

Another major issue is Uganda's soil degradation: the fertility of the agricultural lands is declining, due to increasing cultivation intensities. The average nutrient depletion rate is estimated at 87 kg/ha each year. It has been calculated that for each hectare a yearly amount of 200 kg inorganic fertilizers would be needed to maintain current levels of agricultural productivity (Pandey et al., 2007). However, most rural households use neither organic manure nor artificial fertilizer on their lands. This makes their land vulnerable of losing their topsoil during heavy rains and increases the risks of landslides and flooding of rivers.

2.3.3 Renewable energy in Uganda

Potentially, the use of renewable energy sources can curb the increasing dependence of Ugandans on traditional biomass energy that has been described. The role of renewable energy in Uganda's energy supply, however, has been very marginal up to now. Only 4 % of Uganda's total energy consumption is covered by renewable energy sources (MEMD, 2007). The largest part of Uganda's renewable energy consumption is supplied by three large hydropower stations in Mukono (180 MW), Jinja District (200 MW) Bujagali (250MW). A fourth hydropower plant of 500MW is now being built in Karuma, on the Nile River. The development of more hydropower has been constrained by the growing criticism on the construction of large dams because of their negative social, environmental and economical impacts on the surrounding communities.

There are many other renewable energy sources with quite some potential, however. Various small-scale hydropower plants and biomass-based cogeneration installations working on sugar cane can be found across Uganda. More than ten thousand solar PV units have been disseminated, as well as nearly two thousand biogas digesters. Solar and biogas technologies are only slowly growing however, as many Ugandans cannot afford the large upfront costs of these solutions. In some regions, there is also some potential for wind power and geothermal energy installations, but neither of these renewable technologies has been developed so far.

Different factors are limiting the role of renewable energy in Uganda (Kamese, 2004). The high cost of renewable energy technologies and the lack of awareness about these alternative energy sources have resulted in a limited demand in many Ugandan communities. Another factor has been the lack of financial support and incentives for institutions in the renewable energy sector. A large constraint has been the lack of a comprehensive energy policy which includes the decentralized, renewable technologies in the same structure as the more commercial, conventional energy technologies.

2.4 The Uganda Domestic Biogas Programme

2.4.1 Favorable conditions

In Uganda, biogas has been used as a renewable energy source since the 1950"s (Kahubire, 2010). A variety of factors make Uganda a very suitable location for the further development and dissemination of biogas technology. First, Uganda is a very agricultural society, in which 73 % of the population is farmer by occupation (Pandey et al., 2007). The continued tradition of cattle rearing makes animal manure, the main input for the biogas digester, widely available in most parts of the country. As Uganda lies across the equator, the temperatures in Uganda are fairly constant throughout the year and mostly above 15°C. These are excellent conditions for the fermentation process in the biogas digester, which converts the animal dung into gas.

The fast decrease in soil fertility that resulted from the very intensive agricultural practices has created possibilities for the use of the bio-slurry, an organic fertilizer that is produced within the biogas digester. Uganda is one of the lowest per hectare users of imported fertilizer (Pandey et al., 2007) which makes the adoption of the biogas technology even more valuable for those areas facing serious soil degradation.

Furthermore, Uganda's problematic energy situation increases the demand for local, renewable energy solutions which can make households less dependent on increasingly scarce biomass and an unreliable, expensive electricity network. The impacts of deforestation and Uganda's electricity shortages can make the adoption of alternative energy sources like biogas an interesting option for many rural and peri-urban households.

Finally, Uganda has a set of relatively progressive policies concerning the adoption of renewable energy. Already in 2002, the Energy Policy of Uganda aimed for the development of „the use of renewable energy sources for both small and large-scale applications" (MEMD, 2002). More recently, a separate Renewable Energy Policy was created, which described as its main goal „to increase the use of modern renewable energy from the current 4% to 61 % of the total energy consumption in 2007(MEMD, 2007). For the biogas sector, specific targets were listed. By 2012, the policy document aimed to reach an amount of 30.000 biogas digesters by 2012; a total of 100.000 plants by 2017. These government objectives represent an institutional framework that is very favorable to the development of a nation-wide biogas sector.

2.4.2 Expected benefits

In theory, further dissemination of biogas will improve the well-being of rural households on a range of aspects (Dengeric 2010). First, biogas provides energy for cooking and lighting. A 6 m^3 family-sized biogas digester can convert the dung of three cows into enough biogas to provide 4 hours of cooking and 4 hours of lighting a day (Bos & Kombe, 2009). While animal manure is not methodically composted and integrated into farming practice in Uganda, biogas-digesters can act as collectors of under-utilized dung (Pandey et al., 2007).The residue of the fermentation process in the biogas digester, bio-slurry, retains all the nutrients in the manure (SAC/ADAS, 2007) and can thus be used as organic fertilizer to enhance agricultural productivity.

Biogas energy has some advantages over other renewable energy sources, like solar energy and hydropower. It not only provides energy for cooking and lighting; the technology has also a range of social, economic and ecological benefits (Ji-Quin and Nyns, 1996). First, the transition from biomass to biogas as a fuel for cooking can have enormous environmental impacts, limiting the widespread deforestation process in Uganda, reducing the amount of greenhouse gas emissions and curbing the process of soil degradation. Research on the results of biogas in Nepal (Katuwal & Bohara, 2009) show a significant improvement in the health of members of the household, because they are no longer affected by the smoke of the firewood or charcoal. The reduction in eye infections, respiratory diseases, coughs and headaches varies between 25 and 40 % for women, between 20 and 25 % for children and between 15 and 20 % for men. Changing to biogas significantly reduces the time spent on collecting fuel and cooking, thereby providing opportunities for women to earn additional income or participate in social activities. Rural households can improve their agricultural production with the bio-slurry, while saving on costs for firewood and kerosene.

Apart from those benefits that are felt mostly by the owners of biogas digesters, it is suggested that other people within the community may also experience indirect benefits that accrue from the dissemination of biogas. Although biogas digesters will not be directly accessible to the poorest of the poor, who do not own sufficient livestock and cannot afford to invest in digesters, the dissemination of digesters is said to reduce overall fuel wood and charcoal demand, allowing those disadvantaged households, who most depend on traditional biomass energy, to continue to do so without the constraint of increasingly limited supplies. Uganda already has some examples of successful improved cook stove programs, which together with a national biogas initiative could partially mitigate the looming shortage of fuel supply in rural areas (Pandey et al., 2007).

Other indirect benefits could be identified in the field of health and employment. The collection of animal dung prevents animal waste from attracting mosquitoes and other insects, thereby limiting the spread of diseases like malaria. The job opportunities in areas with biogas can increase, because a number of people will be employed in the construction, maintenance and further promotion of the biogas technology. Often the collection of dung and water, the actual feeding of the digester and the appliance of the bio-slurry are done by workers who are hired by the biogas owner.

2.5 Biogas digesters in Sub-Saharan Africa and other parts of the world

The number of biogas installations across Africa is increasing, largely in the domestic energy sector, due to national domestic biogas programmes in Rwanda, Tanzania, Kenya, Uganda, Ethiopia, Cameroon, Benin and Burkina Faso, each with national targets of over 10,000 domestic systems to be installed in the next five years (Smith, 2013). However, technical, environmental, financial and social questions remain, and the rapid increase in the number of biogas installations means providing scientifically rigorous answers to these questions is of critical and urgent importance (Greg, 2012).

Due to the generally warm climate in Africa, at most locations ambient temperature is sufficient to maintain the fermentation process and no artificial heating is required, and biogas installations are generally based on psychrophilic (<20°C) or mesophilic (30-42°C) anaerobic digestion. Digesters available in Sub-Saharan Africa are of 3 main types: tubular design, floating drum, and fixed dome (Smith, 2013).

2.6 Demand for small scale biogas digesters in Uganda

Interest in use of small scale biogas digesters in rural communities of Uganda, to treat and utilize organic wastes is increasing; with numerous organizations promoting their use for both socioeconomic and environmental reasons (smith. 2012). Small-scale biogas digesters have great potential to contribute to sustainable development by providing a wide variety of socioeconomic benefits (Mshandete and Parawira, 2009), including diversification of energy supply, enhanced regional and rural development opportunities, and creation of a domestic industry and employment opportunities (Rio and Burguillo, 2008). Potential environmental benefits include reduction of local pollutants, reduced deforestation due to logging for fuel, and increased sequestration of carbon (C) in soils amended with the digested organic waste (Lantz et al, 2007). Ecosystem services that are potentially delivered through implementation of biogas digesters in rural communities are C sequestration, improved water quality and increased food production (Ji-Quin and Nyns, 1996). Carbon can be directly sequestered in the soil through application of soil organic matter originating from the digested material (Marks et al, 2009). Indirect C sequestration can also be achieved through reduced C losses due to logging as household fuel is replaced by methane produced by the digester (Mwakaje, 2008). Water quality can be improved through reduced runoff of waste material and reduced erosion of sandy soils due to stabilization of the soil through increased input of organic matter (Yongabi et al, 2009). Food production can be improved by application to the soil of digested material containing readily available nutrients (Onwosi and Okereke, 2009). The productivity of the soil can also be improved through improved soil structure and water holding capacity achieved by the organic amendments of digested material to the soil (Fonte et al, 2009).

2.7 Risks associated with the use of small scale biogas

Despite the high potential benefits, uptake of biogas digesters in SSA is small compared to other developing countries. A range of socioeconomic factors influence uptake (Walekhwa et al, 2009). Possible negative impacts are the potential for pathogens harbored in the digester slurry to infect humans who handle it or eat crops fertilized with it (Yongabi et al, 2009; Brown, 2006), the use of scarce economic and material resources in installation of digesters (Amigun and von Blottnitz, 2009), the potential for water pollution through losses from faulty digesters or from runoff of undigested material that has been applied to soils, and possible leakage of methane before complete combustion to CO2, so increasing the global warming potential of the emitted gases (Rabezandrina, 1990).

Practical problems include prohibitive initial investment costs (Karekezi, 2002) and availability of materials for construction of digesters that will not leak materials or gases (Rabezandrina, 1990). Digesters must be designed to function efficiently in low rainfall conditions (Rabezandrina, 1990). The amount of fuel produced must be sufficient to meet the needs of the households, and this depends on the availability of feedstock from human, animal and plant sourced organic wastes (Rabezandrina, 1990). The use of the fuel produced and the digested product should be socially acceptable to the rural community if digesters are to be adopted (Fox, 1993). Political measures may be needed to encourage adoption, including training and capacity building programmes, flexible financing mechanisms and dissemination strategies (Karekezi, 2002).

2.8 The Three Main Designs of Biogas Digester

2.8.1 Fixed Dome Design

The construction cost of a fixed dome plant is relatively low. However, the costs are almost double in Africa compared to Asia due to cost of materials and transportation (Sara Ocheugu, 2010). The fixed dome is a simple design with no moving parts creating a long life of the plant (upwards of 20 years). The digester is usually masonry construction underground to protect it from physical damage and saving space. The construction of these plants is labor-intensive, creating local employment but should only be built where construction can be supervised by experienced biogas technicians. If construction is poor the digester may not be gas-tight or water proof. The waste enters from the mixing area or latrine house into the material in the digester, as the gas is produced the gas pressure builds up in the dome pushing the material into the expansion chamber where it can be removed. Stirring of the system occurs through the pipe that allows the slurry to exit. The importance of stirring is to limit the formation of a scum layer on top of the slurry that reduces the production of gas (Sara Ocheugu, 2010)

Figure 1 shows the basic diagram of a fixed dome plant with labels indicating the following parts: 1) Mixing tank with inlet pipe and sand trap. 2) Digester. 3) Compensation and removal tank. 4) Gasholder. 5) Gas pipe. 6) Entry hatch, with gastight seal. 7) Accumulation of thick sludge. 8) Outlet pipe. 9) Reference level. 10) Supernatant scum, broken up by varying level.

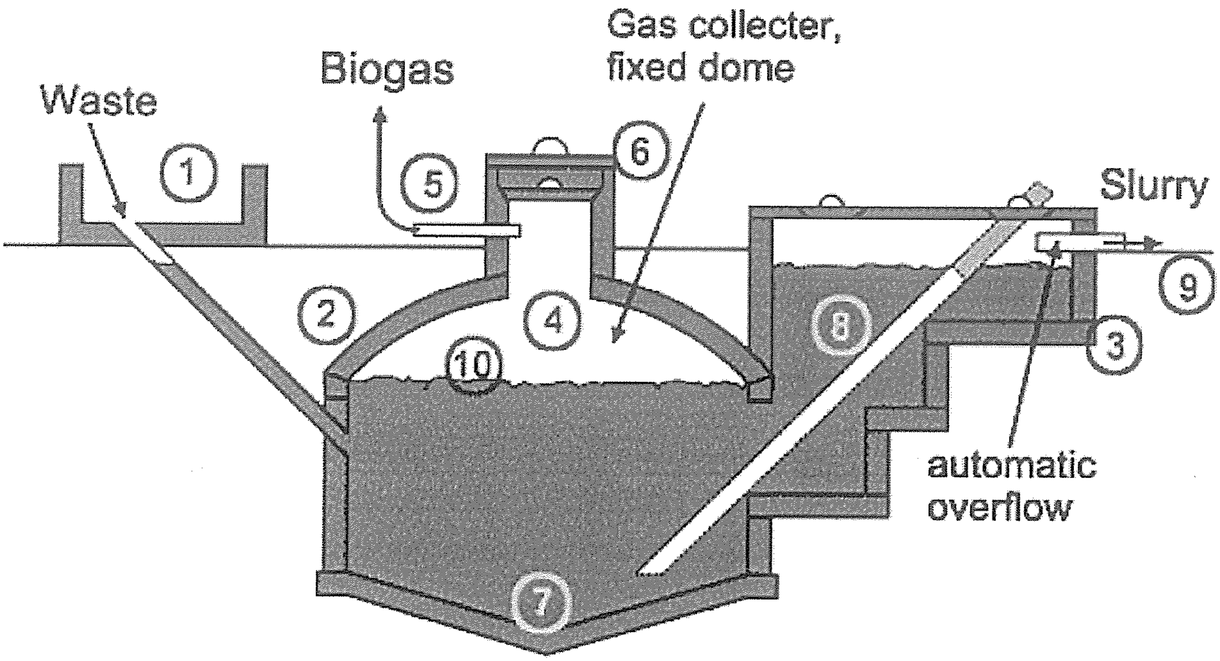


Figure 1: Fixed dome biogas plant (Nicarao design) (Source: GTZ, 2009)

2.8.2 Floating Drum Design

A floating-drum plant consists of a cylindrical or dome-shaped digester with a moving or floating gas-holder or drum located on top. The drum can float directly in the slurry or be located in a separate water jacket. This drum collects the gas for storage and moves up as gas is produced and down as gas is used; this provides a more regulated gas pressure.

The digester can by of masonry work, steel or reinforced plastic. A guided frame is used to provide support for the gas-holder, but the floating drum must not touch the outer walls or tilt, because it can then be damaged or get stuck (Ocheugu, 2010)

Figure 2 shows a plant with a water jacket with labels indicating the following: 1) Mixing area 2) Digester. 3) Gas-holder. 4) Slurry store 5) Gas pipe. And 11) Fill pipe (GTZ, 2009).

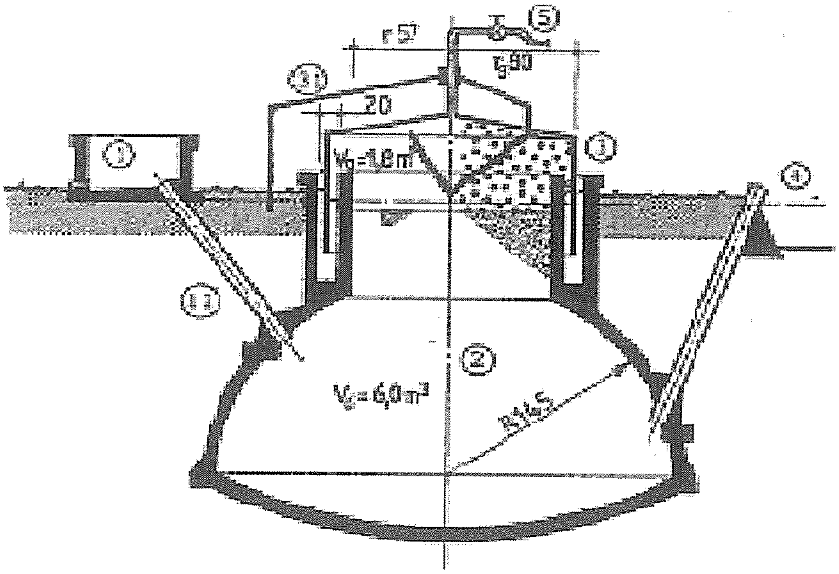


Figure 2: Floating drum biogas system with a water-jacket and external guide frame (Source: GTZ, 2009)

2.8.3 Tubular Design

A tubular system usually consists of two large polyethylene bags and is commonly used on the household level for small-scale dairy farmers (Ocheugu, 2010). As shown in Figure 3, one bag acts as a digester, which lies in a trench to provide protection. Some type of structure should be built above this digester to protect it from UV rays, falling debris, children and animals. The other bag provides storage for the gas before its use. The system is easily constructed and maintained, with a lifespan of about 3 years.

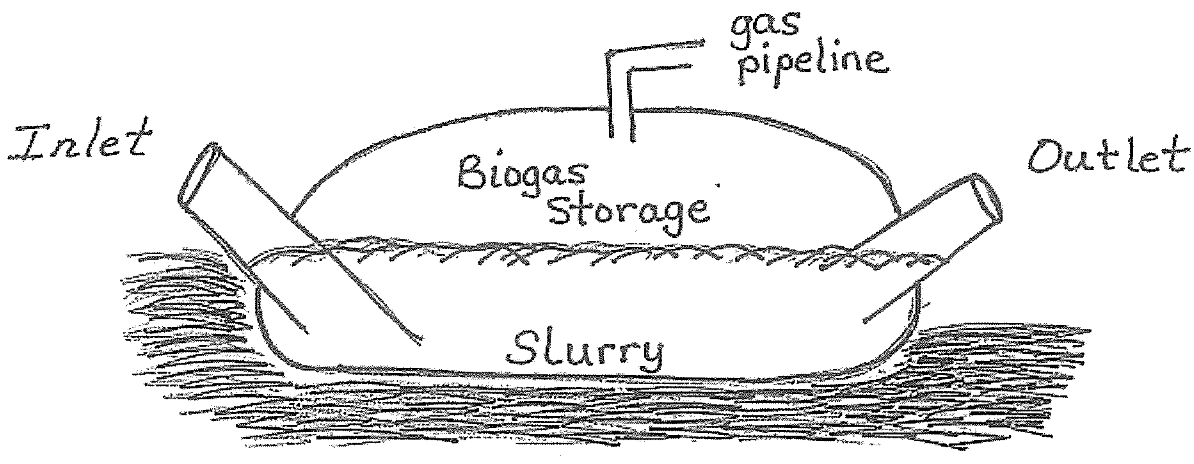


Figure 3: Diagram of tubular system(source; Ochuegu, 2010)

Table 1: Merits and demerits of these three technologies are summarized in the table below:

Technology	Pros	Cons
Plastic tube digester	• Inexpensive technology: Between UgShs 350000-540000 (USD 130-200)	• Very damageable • Short lifespan: 4 years max. • Relatively few successful installations • Not very easy to operate • Dismantling and recycling of the unit
Plastic tank digester	• Easy installation • Quick biogas production start-up after installation (3-4 days) Small digester tank volume, therefore appropriate for limited livestock	• Expensive technology Approximately UgShs. 2590000 (USD 960) for the 1.8 m3 model • Potentially damageable (not underground) • Small digester volume available, hence low biogas production • No employment creation • Few existing installations, hence little feedback • Dismantling and recycling of the unit
Fixed dome technology (Analysis based on the Rwanda design, see Box 1)	• Long lifespan: more than 20 years • Not damageable (underground) • Many references (e.g. 2,700 units in Rwanda, 250,000 units in Nepal for	• Expensive technology Between UgShs. 2349000 and 4050000 (USD 870-1500) • Potentially long durations

	other fixed dome technologies) • Easy to operate • Job creation	before the start-up of the biogas production
Floating drum digester	• Provides constant gas pressure at outlet Visual indication (floating gasholder level above the pit) of the amount of available gas	• Very expensive compared to fixed dome digesters • Steel drum (gasholder) is subject to corrosion • Lower lifespan than fixed dome technology

Source: (Loic, 2013)

2.9 Availability of materials for construction of biogas digesters

Hardware needed for construction of biogas digesters includes burners, metal drums and storage drums (Walekhwa et al, 2009). If a flexible balloon type digester is adopted, materials needed are plastic linings, acrylic tubing, irrigation pipes, Teflon tape, adhesives, and sticker tapes. For a fixed dome digester cement, mud bricks, sand, gravel and shovels are required. Fixed dome or floating drum digesters can be constructed out of more local materials, but the cost may be higher. More studies are needed into the potential of local materials that can be used to produce low-cost flexible balloon type digesters as well as fixed dome digesters. More studies are also needed into possible starter cultures and substrates for digesters including animal and agro-industrial wastes, and waste-water with high microbial burden.

2.10 Integration of biogas for household usage

Contrary to Asia countries, biogas technology has not been very successfully promoted in Uganda, and this is due to a range of social and technical reasons. The technology often needs high levels of skill and supervision for reliable operation and the daily labour input for its operation can be too demanding, particularly when it involves cow dung collection and mixing with water. These issues can be solved by efficient design of the biogas digester and integration of the unit into the farming / household system to require as little human intervention for operation as possible.

The raw material for digestion must be conveniently available on a daily basis (minimum 30 kg of cow manure or 15 kg of vegetable waste or any equivalent), otherwise the technology will not be viable (Sengendo et al, 2010). There must be a need for the energy (and/or fertilizer).The location of the digester should have suitable inlets and outlets to allow the introduction of organic waste and the use of the sludge or overflow water without a large input of labour. The digester should be positioned to minimize transport labour; the gas-line is easily extended (up to a point), whereas the transport of feedstock can be labour intensive. If the digester cannot be built adjacent to the shed, this may mean moving the cattle shed or kraal, or constructing a furrow with a cement base to carry the feedstock from the animal house to the digester. At the same time the digester should be as near to any other feedstock sources (such as the kitchen) as possible.

Wherever possible digesters should be installed where there is a ready flow of wastewater (for example from restaurants, hostels), and wastewater should be used in preference to fresh potable water. Use of water containing detergents from kitchen could adversely affect gas production, so more experimental measurements on the use of waste water in digesters is needed. A wastewater pipe can be installed from kitchen area underground directly to the digester. Solids can be added directly without mixing if inlets and outlets are sized to prevent blockages. We need to utilize an appropriate design to ensure that we don't unnecessarily increase labour requirements, such as by fine chopping of materials. Every step of the process must be implemented to maximize efficiency, including the correct setting and use of appliances.

2.11 Co-digestion of feedstock's for maximum return

Co-digestion uses multiple feed stocks. The C: N ratio and pH of the digest can be adjusted by selecting an appropriate mixture of feed stocks. Co-digestion is key to improving waste management and sanitation. Different feed stocks have different gas yield potentials (figure 2.2). Materials with high C: N ratios, such as waste wheat and bread, typically have a much higher gas yield than materials with a low C: N ratio, such as cattle and pig manure. Co-digestion can be used to selectively improve the biological and nutrient environment in the digester, while increasing available gas and nutrients, and improving waste management. Further research is needed to identify suitable co-feed stocks, either to improve the quality of biogas or to maximize yield gas yield (Smith, 2012).

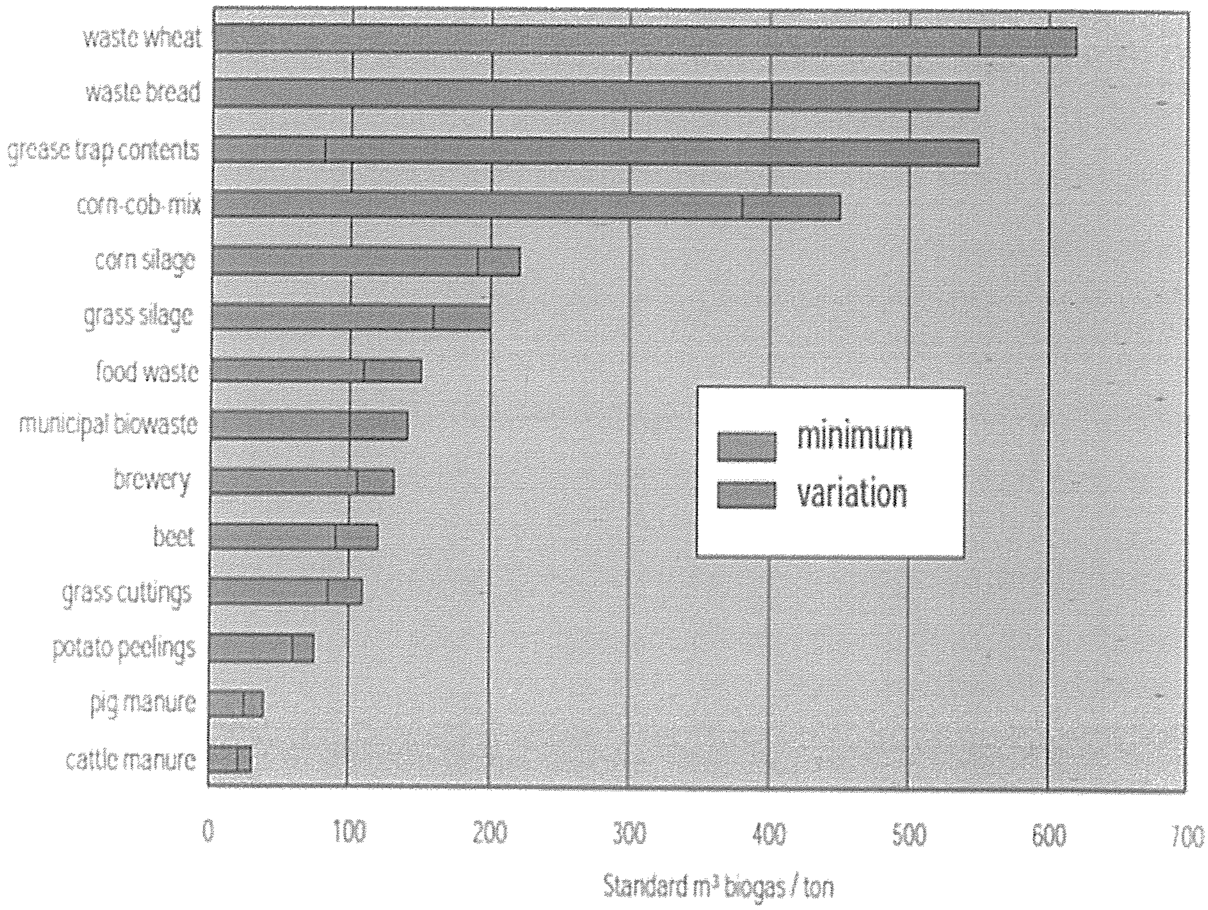


Figure 4: Typical gas yields of different feed stocks (Austin, 2011)

2.12 Socio-economic issues

There is a lack of basic cooking facilities, latrines and hygienic standards within rural areas; over 90% of Ugandan households rely on biomass fuel and 72% do not use improved latrines (WHO, 2000). Biomass fuels require money or time to obtain them, and the lack of hygienic conditions results in health problems, indoor air pollution (392,000 deaths in Africa in 2000 according to WHO), contaminated (drinking) water, and lack of basic hygiene (Klaus, 2011).

In many areas of Uganda, biogas is considered to be a new and dirty technology. A social stigma exists against its use because of social beliefs (Uchiegu, 2010). Many people consider the taste of the food cooked by biogas to be inferior to that cooked on a wood or charcoal stove. These socio-economic factors should be analyzed before beginning a dissemination programme in a particular area, as in some places, the limitations of one or more of these factors could mean that implementation is unlikely to succeed. Efforts to introduce biogas digesters should be focused in areas where socio-economic factors are most favorable, and the choice of digester design should be tailored to maximize the local chances of success.

2.13 Socio-Economic Constraints to Adoption of Biogas

Socio-economic status is based on family income, parental education level, parental occupation and social status (contact within the community, group association and community perception of the family) (Damarest et al, 1993). In a review of socio-economic factors affecting adoption of biogas digesters in 5 countries in Sub-Saharan Africa (Damarest et al, 1993), most factors affecting adoption were associated with costs and ability to pay; family income, size of farm, construction costs, costs of traditional fuels and availability of credit facilities. Other factors were associated with availability of feedstock; number of dairy cattle, average cost of a dairy cow, and land and water availability. Education, awareness, and type (e.g. age and sex) of household head were also factors affecting adoption. There is a need to address country specific requirements for widespread adoption of biogas digesters to be achieved. Costs and subsidies for purchase are important issues that could have a strong impact on adoption. Cheaper materials are needed for construction, and credit facilities are required. Reduction of retention time from 60 to 30 days reduces by half the size of the plant needed, with a significant reduction in construction cost. Awareness of the value of biogas digesters needs to be addressed, using different methods of dissemination, such as electronic and printed media, workshops, field days, demonstrations, and farmer to farmer contacts.

2.13.1 Costs and ability to pay

Analyses of costs and benefits of biogas digesters are often unreliable and uncertain (Quardir et al., 1995); this does not help to promote user confidence and may inhibit future uptake. Only designs appropriate to the specific conditions will perform satisfactory and have a favorable cost-benefit ratio. The size of farm has an impact on uptake; agricultural productivity is inversely related to farm size due to the option to use family labour on a small farm (Lipton, 1993). This then has a similar impact on the ability of the farmer to use family labour to feed the biogas digester, and so impacts successful operation of the digester. Availability of the labour required for daily operation and maintenance of the digester determine whether the digester will be operational in the long term.

Labour is needed for acquisition of dung or other organic materials, collecting water for mixing with the dung, feeding the digester, regular maintenance, and supervision, storage and disposal of slurry. The availability of cheap and reliable appliances, and strong technical support, further increase uptake and long term use of the digester (Kuteesakwe, 2001). The cost of alternative fuels available to the household has a strong impact on adoption: the higher the price of energy replaced by biogas, the higher the probability of adoption. As fuel wood becomes scarcer, biogas becomes a more attractive option.

The initial investment cost is probably the biggest constraint to adoption; in Tanzania, a fixed dome design costs between 700 and 1200 US$, and most rural households and subsistence farmers would consider this an unaffordable luxury unless they receive external support. However, substantial support would be required by governments and aid agencies, and the experience in Asia has been that subsidies do not necessarily encourage long term uptake. Low cost flexible balloon installations, if possible utilizing local materials to reduce production and installation costs, might provide a more economically acceptable solution. A promotion scheme is needed to publicize the multiple benefits of digesters including clean energy, improved sanitation and the valuable fertilizer provided by the slurry. Important marketing issues that must be addressed include packaging, distribution, commercialization, availability, affordability of spares and aftercare service.

2.13.2 Availability of feedstock

The source of substrate for the digester is an important factor; the source must be reliable and sufficient. In Uganda, where cattle manure is a major source of substrate, the number of livestock kept and the use of extensive grazing systems can limit benefits from a biogas digester. African countries generally have relatively low numbers of cattle, compared to India and China who produce 28% and 19% of the world's cattle respectively (USDA/FAS, 2008). (Note that to be directly comparable, these numbers should be reanalyzed in terms of number of cattle per head of population.)

2.13.3 Availability of land and water

A possible barrier to uptake is unavailability of land and water (Quardir et al, 1995). The amount of land required for setting up an integrated biogas unit (biogas plant, animal unit for substrate, fodder unit to sustain the animal unit) can be limiting in some overpopulated areas. All units need to be in close proximity for efficient biogas production. Approximately equal amounts of water and dung are required, amounting to ~60 litres of water per cow per day. In Uganda, 76% of households have water within 1km of their homes (Pandey et al., 2007), but in other parts of Sub-Saharan Africa, water may be more distant. However, re-use of water collected for other purposes (such as washing) can help to alleviate this problem. Community driven approaches to water supply have been initiated (World Bank, 2011), including rainwater collection methods (Kuteesakwe, 2001), and these have great potential to increase uptake.

2.13.4. Education, awareness, and type of household head

Awareness of the value of biogas may be another factor inhibiting uptake (Bhat et al., 2001). Multiple agencies are currently attempting to increase awareness, including private enterprise, promoters, catalysers and user interest groups. Lack of education may present a barrier to uptake. Although formal credit markets have become increasingly accessible to farmers, farmers lacking a high level of literacy may find the complicated borrowing procedure and paperwork a major disincentive (Vien, 2011). This is supported by the observation that adoption increases with literacy rate (Bhat et al., 2001).

2.13.5. Marketing approach

Another reason for low adoption of digesters in Africa is that the technology is too expensive for wider dissemination, especially to low-income target groups (Vien, 2011). This problem could be addressed by the extension approach chosen: one possible, but controversial approach is to start where the money is (just like in any other new business), rather than targeting the poorer households (Vien, 2011). Whether we are aiming at full energy offset or partial fuel substitution by biogas has an influence on how and what we communicate to potential beneficiaries, and what technologies we use. A precondition to adoption must be that the customer has the necessary funds for the investment available. Whether this is achieved by targeting richer households, by subsidizing the more expensive but robust designs of digesters, or by opting for less robust but more affordable digesters is still a matter for debate. Further socio-economic research is needed to inform these decisions.

2.13.6 Potential Environmental Benefits Of A Biogas

The potential environmental benefits of a biogas digester to the householder are in the provision of energy, the disposal of organic wastes, the improvement of air quality and the provision of a valuable organic fertilizer (Robin, 2009). To the wider community, the benefits include reduced loss of biodiversity and carbon due to deforestation, improvement in water quality and increased carbon sequestration in the soil (Omer and Fadalla, 2003). However, whether these benefits make it worthwhile for the householder to invest in a biogas digester or for the wider community to support the installation of digesters must be quantified, and balanced against socioeconomic costs and benefits.

2.13.7 Potential Risks To The Environment

However, biogas digesters can also introduce potential risks to the environment (Arnold et al, 2003. These include contraction of diseases due to increased handling of fresh wastes and the digested product, possible pollution of water courses due to leaks of organic waste from faulty digesters and incomplete sterilization of slurry during digestion, and increased global warming due to leaks from faulty digesters and intentional venting of methane from some designs to avoid pressure build up. These issues are complex, and rigorous quantification of the different factors is needed to ensure the huge potential benefits of biogas digesters are realized.

CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Introduction

According to Charles C. Ragin, social research is about trying to match ideas with evidence. The aim of this study as stated previously is to assess the possibilities of producing biogas in rural communities in Warr Sub County, especially for the benefit of rural women considering the fact that integration of biogas technology has been successful elsewhere in other part of the country. This was done by exploring the experiences of the rural community with energy situation there and assessment of the feasibility of biogas usage. This chapter therefore presents and discusses all the processes that were considered and employed in the collection and processing of the data to serve as supporting evidence for this research. It also touches on the research design adopted, the target population, sampling size and technique used as well as the instruments used to process the data.

3.1 Type of research method

The aim of collecting the data is to get a hold of the different experiences the rural people in Warr Sub County have encountered with their energy sources and possibility of using biogas as an alternative energy source in the local communities. The aim was therefore to interview people in these villages at their household level.

The study was intended to be exploratory and discursive hence the need to use qualitative methods. This could not be achieved by a single qualitative method so a method of triangulation was employed at various stages of the study. Triangulation involves the use of several methods at a time so that the methods complement each other. The strength of one method helps to overcome the weaknesses of another thereby achieving a cost benefit analysis balance, (McIntyre 1999). The qualitative methods triangulated in this study include interview, informal discussions and observation.

3.2The Study Area and Target Group.

The study was conducted in Warr Sub County in three villages of Agiermach, Ukemu and Padhuk. These are typical villages that are experiencing rapid population growth like many other villages in the sub county. This study was conducted on household basis. In each village at least ten household was interviewed. The target groups were the household that at least own some animals like cattle, goats and pigs. The finding I got for this report was assumed as from the whole sub county.

3.3 Sample Size

In all a total of thirty respondents were selected for this study. As mentioned before, this study is more about representing the diversity of experiences as such a large sample was not my focus but rather a small sample to represent variety. The table below represents the villages and the number of male and female interviewed.

Table 2: Sampling Distribution

Institution	Number of Females Interviewed	Number of Males Interviewed	Total Number of People Interviewed
Agiermach	7	3	10
Ukhemu	6	4	10
Padhuk	7	3	10
Total	**20**	**10**	**30**

Source: Fieldwork 2014

3.4 Source of Data

The source of data for this study was both primary and secondary data.

3.4.1 Primary data

This involved collection of data from respondents in a given area who are living there. This was the first hand data that was organized and compared with the secondary data for better reporting of the situation.

3.4.2 Secondary Data

The secondary data was acquired from reports which had been compiled by field researchers, magazines and papers that concern the biogas technology and its potential in other areas. Secondary data helped me to analyze the social economic situations in the communities to the best biogas design that can be used easily in the community.

3.5 Data collection methods

3.5.1 The Interview

The aim of the interviews conducted was to find diversity of experiences in villages. Rather than administering a questionnaire an interview guide was used so as to bring out the actual perceptions of the interviewees and also to explore other issues that the questionnaire may not have covered. Though the interviews were scheduled, they were conducted in a very informal and relaxed manner in order to avoid the situation where respondents feel intimidated though I must confess that some of my interviewees did feel uncomfortable disclosing their asset and how much they earn. I used The interview guide question to do the interview (appendix 2)..

3.5.2 Observations

The data gathered from interviews was supplemented by observations I made as a researcher. Observing body language such as respondent's countenance, enthusiasm or hesitance, the researcher can tell when to probe further or how to pose a question in order to get the right information without touching any emotional buttons.

However, sometimes body language can be deceptive especially when the researcher is studying a totally foreign culture. In such instances, an attitude which the researcher might interpret as hostile may rather turn out to be a sign of welcome.

3.6 Data Analysis

Data analysis involves all processes and procedure whereby we move from data collected to some form of explanation, understanding, interpreting and basically making sense out of the data (Strauss and Cobin 1990). The processes are; writing, coding into themes and then finding out what available literature there is regarding the research topic. Remaining open minded was all what was necessary when analyzing the data.

3.7 Validity and Reliability

The research methods that were intended to be used are questionnaire and interviews. The interview questions guide was cross examined for approval by the research expert, to ensure that the information they will generate is appropriate and consistent.

3.8 Ethical consideration

This involves seeking permission by the researcher from the senior leaders of the study area. I did the interviews in the village of Agiermach, Ukemu and Paduk under the consent and knowledge of the local leaders in those villages. I had permission from the village Local Council one .I also notified the LC IV of Warr Sub County. Mr. Adegi. I was able to do my research without any form of harassment.

3.9 Limitations of the Study

No research design is perfect, (Patton 2002) and it applies to this study as well. Several limitations can be pointed out in this study but then the design of the research is subject to the kind of data that is being sought after for the study.

The perspectives and direction of the study was based on interviews with not more than thirty household as a whole, implying that conclusions might not be drawn from the outcome since it will be over generalized. However as explained earlier, this study is not to represent the views of all but rather to understand the energy situation in the area and determine the biogas potential.

Time and financial constraints did not give me the flexibility to visit as many rural communities as would have been desired. Ideally I could have gone to other villages in Warr and gained additional information. These limitations however do not affect the authenticity of the study and so a lot of lessons can still be learnt from the outcome of this study.

3.10 Maintaining Objectivity

Remaining objective is quite challenging when there is prior knowledge of situations on the ground, for instance in the case of this study, being a resident of Agiermach for a long time prior to the study I was aware of the attitude most rural communities in Zombo display: they wait on the central government to initiate and fund all projects concerning them. The temptation to look at the issues with previous knowledge was constantly there. It does not however mean that my personal impressions and opinions as a researcher are completely wrong or invaluable for the study. However, had I been an outsider, I would have asked more questions and obtained more from the interviews than I did. There may have been an element of complacency on my part as a researcher simply because of my native background. It was possible therefore for a qualitative study to be completely objective without any hint of subjectivity from the researcher.

CHAPTER FOUR
DATA PRESENTATION AND ANALYSIS

4.0 Introduction

This chapter presents the report information of the research which is in three main sections (A, B and C), according to the objectives of the study. In this chapter much of the data were got from the field. However some secondary data were used here to give guide to arrive at clear and meaningful conclusion in the next chapter. Information is described both in figures and words. The use of tables and figures in percentages was to ease understanding of the reader by generalizing some data.

4.1 Energy Situation in Rural Villages: Warr-Sub County

4.1.1Energy Sources in the Communities

In rural Uganda where there is no access to electricity, 95.5% all households use firewood according to (Kabuhire, 2010).Table 1 shows that almost all households interviewed in the village of Ukemu, Agiermach, and Paduk used firewood as fuel.

Table 3: The use of energy sources by rural household (as percent of households)

Types of fuel	Ukemu (%)	Agiermach (%)	Paduk (%)
Wood	100	100	100
Dung	30	10	N/A
Crop residue	20	10	10
Paraffin	70	100	100
Gas	N/A	N/A	N/A

NA= Not Available

Source: field data, 2015

The table above shows that other forms of non-commercial energy are also consumed in Warr sub-county, but they are not as important as firewood. Crop residues are the most common but it is mainly used as supplement for firewood. Cow dung is sometimes consumed but they are not a common source of energy. Paraffin seems to be the most commercial energy sources in the villages. The use of this form of energy seems to correlate with shortage of wood and affluence. But paraffin is basically used for lighting at night. in village like Ukemu the community often run short of paraffin because of bad roads and being far from the nearest trading center. Villagers resort to burning wood and crop residue for longer time to burning wood and crop residue for longer time to keep them warm and light the evening for them. There were no family were the use of biogas can be found.

4.1.2Scarcity of firewood

The actual scarcity of firewood by source and quantity results from interaction between supply and demand and the strategy of the users. Considering the figures in table 1 imply that there is already high demand for firewood. With increasing population in the villages there is high tension and uncertainty about the future source of firewood. Most of the areas that were under natural vegetation and supplied firewood to the community are being rapidly converted to garden and settlement area.

The table below summarizes the response and suggestion by the men and women interviewed in Warr Sub County

Table 4: Fuel scarcity

Most common source of fuel wood	Trees left in farmland Planted trees Neighbor's village land Sellers/vendors Private forest reserve
Average distance travel in search for fuel wood	20km
The time it takes when searching for fuel wood	8hours
Average number of fuel wood bundles used per month	6
Average amount of charcoal used per month	1basin
Most response about the problem of fuel wood	Serious
Solution to wood fuel shortage	Plant trees Prevent bush fire
Alternative energy suggested	Electricity Improved energy stoves Biogas
Alternative energy most used now	None
Cost of fuel wood per bundle	4000/=
Cost of charcoal per basin	3000/=

Source: Field Data, 2015

Many household depends on trees in their garden, were they are obtaining quick source of fuel wood and crop residues. Some few people who own more garden with trees earn some good amount from selling dry branches. Charcoal is not produced any were within the three community but brought from far village only on market days.

4.1.3 Local strategies to cope up with the wood scarcity:

By analyzing the information from the people interviewed in the three villages there was a clear indication that as far as firewood is concerned, the demand has increasingly exceeded it supply so far users have a number of options to respond to this situation. The respond received from the different families when ask their strategies to obtaining and preserving firewood were as shown in table 5.

Table 5: Strategies to obtaining and preserving firewood by households.

Strategy	Percentage responses (%)
Spend more time and/or labour in collection of wood	80
Resort to less preferred species	40
Cook more efficiency	20
Cook less meals	50
Use more substitutes for wood	20
Buy wood	20
Plant trees (woodlots, trees on compound)	50
Cut live wood	70

Source; field data2015

These strategies all provided feedbacks to the demand and sometimes supply. According to (White, 1979) strategy one and two refer to the size of collection area and the species collected. Strategies three and four imply a decrease in firewood consumption; strategy six induces an increase in trade. Finally, strategy seven results in additional land claims primarily used for firewood production (woodlots) or for more trees around the homestead, and lands with a time-lag of 10-20 years the supply of firewood near homestead increases. The various adaptation strategies to fuel wood shortage can be used as indicators of firewood scarcity.

4.1.4Summary

Therefore in most of the villages in Warr Sub County, shortage of firewood has become a problem. This was largely contributed by the increasing population growth and conversion of land areas into cultivation areas. In future more household will use less desirable material like agricultural waste and cow dung as source of energy. The commercialization of firewood is going to intensify if no aggressive measure is taken to address the energy challenge in these communities. The energy situation also provides a view of high need for alternative energy like biogas which has been assessed in the following section.

4.2 Biogas Feasibility Indicators and Needs

4.2.1 Introduction

The biogas feasibility assessment was done using indicators such as; the degree of awareness, attitudes toward biogas usage, social economic situation, availability of materials, livestock keeping and natural resource availability. As presented in the different tables below.

4.2.2 Awareness;

The level of awareness indicates the knowledge about biogas technology.

Table 6: Summarizes the level of awareness about biogas technology in Warr Sub County

People who have heard about biogas	Yes 75% No 25%
People who have adopted biogas technology	None
Sources of information about biogas	Study tour NAADS Politicians
Reasons for not adopting biogas technology	High technology cost Need more information It is too much demanding of labour We don't have money Fuel wood is better

Source; field data 2015

4.2.3Attitudes toward Biogas

The attitudes about biogas can be positive or negative. When the attitudes of the majority are positive it means the likelihood of many people accepting to use biogas at their household. Table 6 and 7 presents the summery peoples attitude toward biogas technology.

Table 7: Attitudes toward Biogas

Comment on biogas technology as alternative energy source	It is appropriate technology 70% It is inappropriate technology 30%
Recommend on biogas technology promotion	Strongly recommended 7% Moderately recommended 60% Not recommended 33%
Most answer; if you are given a total of Ugshs. 3million.What will be your priority of investing?	Build bigger house Start petty business Livestock production

Source; field data 2015

Table 8: Percentage response obtained on Attitudes towards Biogas

This was based on Strongly Agree (SA), Agree (A), Undecided (UD), Disagree (DA) Strongly Disagree (SD) statement.

STATEMENT	SA	A	UD	DA	SD
• Biogas will solve the problem of fuel wood for cooking	0%	24%	50%	0%	0%
• Biogas technology will help to improve soil fertility	10%	40%	50%	0%	0%
• Biogas technology help to improve hygiene due to the use of waste	0%	10%	90%	0%	0%
• Biogas technology will reduce the rate of deforestation	0%	67%	33%	0%	0%
• Biogas will relieve women workload and save time used for fuel wood collections.	0%	67%	33%	0%	0%
• Generally benefits of Biogas technology over weighs limitation/weakness.	0%	0%	7%	83%	10%
• Government and other stakeholders have not sufficiently promoted biogas technology	0%	100%	0%	0%	0%

Source: Field Data 2015

4.2.4 Household Social Economic Assessment

Biogas technologies require a lot of material and financial commitment for one to install them. As (Loic 2013) show that there are different digester sizes and all of them cost differently; the plastic tube digester (UgShs 350,000 – 540,000)' Plastic tank digester (2,590,000 (USD 960),

Fixed dome technology (UgShs. 2349000 - 4050000) and Floating drum digester (2,500,000/= and above). The financial status of a household can determine the adoption of biogas technology.

Table 9: Household Social Economic Assessment

Number of household headed by male	100%	Males make most of the decisions for the family
Average number of people in a household	5	Extended family are mostly
Common level of education attained by the head of households	Ordinary level of education	Most are school dropouts
Common occupation	Crop farming Local engineers (fundi) Petty business Livestock keeping Higher service to government or NGOs	Most are peasant farmers
Common source of income	Crop production Livestock Help from relatives working Business Local construction works	Crop production
Average monthly income per household	30,000/=	

Source; field data 2015

4.2.5Livestock Keeping

People in Warr Sub County keep various types of livestock. Most families keep more than 2 types of livestock. The main method of livestock management is semi grazing were the animals are tethered and sometime left to graze freely. Table 10 present the average number of livestock types kept the by different families in Warr Sub county.

Table 10: The average number of various livestock type per household.

Type	Average number	Management
Cattle	5	Semi grazing
Goats	4	Semi grazing
Sheep	2	Semi grazing
Pigs	2.5	Semi grazing
Donkeys	None	,,,,,,,,,,,,,,,,,,,,,,
Chicken/duck	9	Free range system

4.2.6Assessment on availability of resources

Resources like water are required for daily running of biogas, fuel wood scarcity increases the demand for alternative like biogas and grazing land availability provides a sure way of obtaining feeds for livestock and getting enough dung for biogas generation. The table 11 below presents the summary after the assessment of the resource availability

Table 11: Resource Availability

Water for domestic use	Readily available
Fuel wood for cooking	Is in short supply
Grazing land for livestock	Is in short supply

Sauce; Field data

4.3 Potentials of Biogas in communities

4.3.1 Factors that affect Biogas Production

(Rai, 2000) says the ideal temperature for methane producing bacteria is about 35°C, just about blood temperature. Low temperature reduces gas production and nearly stops at 10°C. Plants built underground tend to have stable temperatures within daily allowable fluctuation of 1°C and in Zombo the minimum is 17°c. The time required for the organic matter to be digested in the digester is called the retention time and is temperature dependant. The higher the temperature the faster the bacteria use the food in the slurry and the sooner it needs replacement. Methane producing bacteria are anaerobic, thus air should be excluded. Bacteriology multiplication depends on the sort of dung and the temperature level. Carbon (in the form of carbohydrates) is utilized for energy provision for the bacteria and Nitrogen (as proteins, nitrates, ammonia. etc) is the chief nutrients of anaerobic bacteria. The required ratio according to (Mathur and Rathore, 1992) is 25- 30:1. At any given time, the bacteria will find its own pH level and this is usually 7-8, but can have ±0.5. This is checked using a litmus indicator paper. Suitable solid content (dry matter concentration) is 7-9%. More water results in more CO_2 produced, while more solid content result in scum formation all affecting gas production, therefore need for control and balancing. Toxic and harmful substances result from medications and type of feeds given to the animals, but the effect is so minimal that can be ignored.

4.3.2 Field Survey of materials requirement for biogas

Assessment of the number of cattle per household was carried out to establish the raw material requirements for the plant sustainability. Preliminary surveys to identify the availability of the water and local materials for construction and to assess the condition of the proposed sites were also carried out. The number of persons per household was found to be seven and they showed willingness to use biogas. The analysis and design was based on the information obtained from other scholars like (Rai, 2000) and field data. The average number of cows per household was found to be 5, and the quantity of dung per cow was experimentally estimated to be 10Kg! cow per day, during worse period of dry season. For the design this study adopted 6 persons per household as per the population census of 2002.Thc success of a biogas plant in the rural areas primarily depend on the selection of the plant design, size, site, materials of construction, type of plant, method of construction and acceptability. Monitoring its operation, repairs and maintenance are required for optimum working and utilization.

4.3.3 Components of Biogas Plant

A complete biogas plant will have the gas generation subsystem (the digester), feed and slurry handling sub-system (the inlet and outlet of the slurry), gas distribution and utilization sub-system (the pipe work and terminal appliances) refer to figure 2.

4.3.4 Selection of Model, Design and Construction

This was based on technical, economic and social considerations. The size to use depends on the availability of biodegradable materials and amount of gas required. In this case the quantity of cow dung and the use of the gas (cooking and lighting were considered). To design for the volume of plant, knowledge of gas required per day, number of cattle available, number of family members (requirement of gas for cooking and lighting), purpose and, hydraulic retention time were the factors of interest. Construction time and labour resources required to build a biogas plant vary depending on several factors. The most important consideration is the availability of people interested in carrying out this kind of work. A biogas digester which is the apparatus used to control anaerobic decomposition was proposed to be constructed of brick masonry. This is a sealed tank or pit that holds the organic materials, and some means to collect the gas that is produced. Many different shapes and styles of biogas plants have been experimented with: horizontal, vertical, cylindrical, cubic, and dome shaped. This study project adapted the dome shape shown in figure 2. The bottom line is that the construction should be simple with low demand of materials, cheap labour and low in cost and easy to build. The foundation is constructed using the plain concrete slab of grade 25. The wall (Plastered) should be impermeable to avoid percolation of water from the sides. The slurry mix tank (inlet chamber) is also provided using masonry construction. Its size is decided such that it can hold charging material for at least one day. It is fitted with a pipe which leads into the digester. The outlet chamber, manure pit, drying bed is constructed having an outlet pipe leading the digested slurry from the digester into the chamber where it is removed and utilized as manure. The gas is lead out from the top of the dome to a pipe network for consumption.

4.4 Biogas Design and Dimensions

4.4.1 Calculations

The number of cows per household as found on average = 8.

The amount of dung per cow = 10 kg given the fact that the cows move far from home to graze.

However, with zero grazing practice a dairy cow produces about 55 kg of dung per day.

The amount of dung to be used for the design therefore = 8 x 10 = 80kg per day.

4.4.2 Gas requirement per day

Size of household = 6 persons on average, (Uganda population census, 2002).

Cooking: -

Quantity of gas required for cooking per person = 0.227mb (Rai, 2000).

Therefore, required gas per day per household = 0.227 x6 = 1 .3 Sm3 of gas.

Lighting

Quantity of gas required for lighting per 100 candle lamps (i.e. 60 watts electric bulb) = 0.1 25m3 per bhp-hour (Rai, 2000). Assuming 3 lamps are required per household for 3 hours per day, required gas per day per household = 0.125 x3x3= 1.1 3m3 of gas.

4.4.3 Total volume of gas required:

Gas required for Cooking + Lighting= 1.35 m3 + 1.13 m3 = 2.45 m3 of gas. Take 2.5 m3 of gas for design. Basing on the amount of gas required per day, 1 kg of fresh dung produces 0.05m'of biogas, (Duggal. 2002), this implies for 2.5 m3 = 2.5 /0.05= 50kg of dung per day. Number of cows= 50/8 = 6 cows. This is adequate compared to household average of 8 cows.

4.5 Benefits of Biogas:

a) Cheap and reliable source of domestic energy.

b) Reduce foreign currency expenditures on electric appliances.

c) Methane being a green gas, its domestic use for cooking and lighting will greatly reduce its release to the atmosphere.

d) Thousands of metric tons of round wood cut for firewood and charcoal will be spared leading to natural conservation of the environment, in line to MDG 7.

e) Sicknesses due to the use of firewood and charcoal will be history.

f) There will be job creation in form of construction and maintenance of biogas plant (MDG1).

g) Will lead to improved economic status of the population as the energy and time spared from collecting firewood may be diverted to other activities like farming which will reduce hunger.

h) May encourage cattle keeping which economically will provide milk, meat and also be used for plowing.

i) Effluent use as fertilizer will lead to improved agricultural output which is in line to MDG 1 (Eradication of extreme poverty and hunger).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents a summary and conclusion of the main findings of the study, based on which conclusions and recommendations were made.

5.1 Findings

5.1.1 Findings on objective one: *To examine the energy situation in the communities of Warr Sub County, Zombo district.*

From the findings, it can be deduced that the energy situation in Rural Villages of Warr Sub County is such that; - the available sources of energy is wood fuel (firewood) which is mostly used by over 95.5% of the households, followed by cow dung, crop residue and paraffin. Crop residues are the most common but it is mainly used as supplement for firewood. Cow dung is sometimes consumed but they are not a common source of energy. Paraffin seems to be the most commercial energy sources in the villages. The use of this form of energy seems to correlate with shortage of wood and affluence and paraffin is basically used for lighting at night. The Villagers resort to burning wood and crop residue for longer time to burning wood and crop residue for longer time to keep them warm and light the evening for them.

The findings also revealed an acute scarcity of firewood (wood fuel), which is the most used source of fuel in the villages of warr sub county. This has been largely caused by the increasing population in these area which causes high tension and uncertainty about the future source of firewood. Most of the areas that were under natural vegetation and supplied firewood to the community are being rapidly converted to garden and settlement area.

This finding corresponds with empirical findings of other scholars like Kabuhire, 2010, who argued that 95.5% of households in Uganda's village use firewood as the main source of fuel than other source of energy like electricity, biogas, paraffin, gas among others.

5.1.2 Findings on objective two: *To assess the biogas feasibility indicators in the rural communities of Warr Sub County, Zombo district.*

To this objective, The biogas feasibility assessment was done using indicators such as; the degree of awareness, attitudes toward biogas usage, social economic situation, availability of materials, livestock keeping and natural resource availability. The finding is as shown below. On the level of awareness;- Most respondents (75%) revealed that they were aware/have heard about biogas through study tour, politicians, and works of National Agricultural Advisory Services, but have failed to adopt it because of high technology costs involved, lack of adequate information about biogas, lack of enough money and easy accessibility of the affordable fuel wood.

In regards to the attitudes towards biogas, the findings revealed that respondents (70%) think that biogas as an alternative source of energy is an appropriate technology, who moderately recommended its promotion.

On socio-economic assessment, the findings revealed that most respondents confirmed that biogas technologies require a lot of financial and non financial commitment to be installed. This depends on the size and ranges from Uganda Shillings 350,000 to 5,000,000.

In regards to Livestock keeping which will provide the main source of raw material for biogas production, the findings revealed that most people in Warr Sub County keep various types of livestock. Most families keep more than 2 types of livestock. The main method of livestock management is semi grazing were the animals are tethered and sometime left to graze freely.

The findings on availability of resources revealed that Resources like water are required for daily running of biogas, fuel wood scarcity increases the demand for alternative like biogas and grazing land availability provides a sure way of obtaining feeds for livestock and getting enough dung for biogas generation.

These findings serve to confirm the findings of empirical scholars who argued that for the adoption of biogas technology to be adequate, some level of awareness have to be in place (Bhat et al., 2001), some level of technology (which is always expensive) have to be adopted (Vien, 2011), requires substantial amount of water and land (Quardir et al, 1995, Pandey et al., 2007, World Bank, 2011 and Kuteesakwe, 2001).

5.1.3 **Findings on objective three:** ***To assess the technical potential of biogas system in the rural communities of Warr Sub County, Zombo district.***

The findings to this objective are as shown in the following discussions. The technical potential for biogas production requires a number of requirements which include, but certainly not limited to; ideal temperature (35°C) for methane producing bacteria. The number of persons per household was found to be seven and they showed willingness to use biogas. The average number of cows per household was found to be 5, and the quantity of dung per cow was experimentally estimated to be 10Kg per day, during worse period of dry season. For the design this study adopted 6 persons per household as per the population census of 2002.Thc success of a biogas plant in the rural areas primarily depend on the selection of the plant design, size, site, materials of construction, type of plant, method of construction and acceptability. Monitoring its operation, repairs and maintenance are required for optimum working and utilization. This finding confirms the earlier findings of scholars like (Rai, 2000).

The findings also revealed that a complete biogas plant will have the gas generation subsystem (the digester), feed and slurry handling sub-system (the inlet and outlet of the slurry), gas distribution and utilization sub-system (the pipe work and terminal appliances). The size to use depends on the availability of biodegradable materials and amount of gas required. In this case the quantity of cow dung and the use of the gas (cooking and lighting were considered). To design for the volume of plant, knowledge of gas required per day, number of cattle available, number of family members (requirement of gas for cooking and lighting), purpose and, hydraulic retention time were the factors of interest. Construction time and labour resources required to build a biogas plant vary depending on several factors. The most important consideration is the availability of people interested in carrying out this kind of work. A biogas digester which is the apparatus used to control anaerobic decomposition was proposed to be constructed of brick masonry.

The findings further showed the relevance of the use of biogas to include Cheap and reliable source of domestic energy, Reduce foreign currency expenditures on electric appliances, Methane being a green gas, its domestic use for cooking and lighting will greatly reduce its release to the atmosphere, Thousands of metric tons of round wood cut for firewood and charcoal will be spared leading to natural conservation of the environment, in line to MDG, Sicknesses due to the use of firewood and charcoal will be history and There will be job creation in form of construction and maintenance of biogas plant (MDG1) among others.

5.2 Conclusion

Basing on the findings of this project work in the previous chapter, the following conclusions and recommendations have been reached.

a) At a cost of UgShs2,400,000($. 870) and 4-6 herds of cattle required for fixed dome design, financially no family can meet the requirements. However at a cost of 500,000/= between 5- 8 people can acquire a plastic-tube digester design to meet their daily cooking and lighting energy for between 2 to 3years, (shausul and Naimul, 2006). The average of 8 cows is adequate.

b) The fixed dome type biogas plant may not be afforded by the majority because of high cost and low income level at households.

c) The major economic activity of the rural populace in this study area is subsistence farming and animal keeping. which provides disposal system for the by- product of the biogas plants in form of manure /fertilizers.

d) The situation on the ground shows that there is low potential to utilized biogas for daily cooking lighting activities however this is mainly due to financial limitation. There are high needs but commitment is very low.

5.2 Recommendations

It is recommended that:

a) Biogas being clean energy source, reliable and easy to construct can be sustainable, and as such is a necessary technology which needs exploration to benefit the rural population.

b) There is need to sensitize people about the use of biogas as a cheap, reliable source of energy.

c) Government should come in to promote the use of biogas through financing of the construction at a community level or initiate the creation of biogas loans. This can be a good supplement to the ongoing rural electrification program.

d) Need for training technicians in biogas technology as it is a new thing.

Concerning the Firewood Crisis

A part from the users themselves, government can intentionally or unintentionally influence the energy consumption pattern. The former offers various options;

e) Ensuring accessibility to substitutes like biogas and electricity, including price regulations,

f) By stimulating the use of improved equipment thus increasing the efficiency-rate,for example designing of stoves and extension work,

g) By promoting woodlots or other forms of tree planning and

h) Finally by the acknowledgement of firewood collection as a form of land use to be recognized in land use planning. This would imply an assessment of the effects of the changes in other forms of land use on fire wood collection and more general, rural energy consumption. Currently the government policy and action are not satisfying to this energy demand.

5.3 Areas for Further Study

1. More research needs to be done to ascertain the biogas and its potential in the local communities of other regions of Uganda to confirm the findings.
2. Further research needs to be done to find out the level of adoption of biogas technology in developing countries like Uganda.
3. More research needs to be done to examine the role of the Government of Uganda in the adoption of Biogas Technology in the Country.

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APPENDICES

APPENDIX 1: HOUSEHOLDS QUESTIONNAIRE ABOUT BIOGAS TECHNOLOGY;

PART 1

A: General Identification

1. Date of interview ....
2. Name of the respondent ....
3. Village ....
4. Ward ....
5. Division ....
6. District ....

B: Household/Institution information

7. Sex of the head of household; 1 = male, 2 = female ( )
8. Age of the head of the household (Years) ( )
9. Provide number of people in each age groups in your household;

Age group	Number	Those who do provide labor
Infants 0 – 10 years Children 11– 18 years Youth 19 – 60 years Adult, more than– 60		

10. What is your highest level of education?
    - (i) Never attended formal education ( )
    - (ii) Below Standard Seven ( )
    - (iii) Standard seven ( )
    - (iv) Secondary Education ( )
    - (v) College Education ( )

11. Main occupation of the head of household;

(i) Farming ( )

(ii) Livestock keeping ( )

(iii) Petty Business ( )

(iv) Wage employment ( )

(v) Others (specify) ....

12. Secondary occupation of the head of the household;

(i) Farming ( )

(ii) Petty business ( )

(iii) Big Business ( )

(iv) Livestock keeping ( )

(v) Others (specify) ....

C: Household Income

13. What are the sources of income for your household?

(i) Farm production ( )

(ii) Livestock keeping ( )

(iii) Business ( )

(iv) Wage employment ( )

(v) Others (specify) ....

14. What is your average income per year Ugshs ....

D: Livestock keeping

1. Indicate number, and management system of the various livestock types in your farm.

Type	Number Kept	Management	Key to management System
Cattle			
Goats			1 = Zero grazing
Sheep			2 = Semi grazing
Pigs			3 = Open grazing
Donkeys			
Chicken/ducks			
Others (specify)			

PART2: Assessment of the energy situation in the communities

16. Are the following resources available in your area?

Resource	Availability (use key)	Distance to the resource (Kms)
Water for domestic use		
Fuel wood for cooking		
Grazing land for livestock		

Key on availability of resources

(i) Readily available

(ii) Is in short supply

(iii) Not available

17. What is the major source of fuel for domestic uses?

(i) Fuel wood and charcoal ( )

(ii) Electricity ( )

(iii) Solar energy, wind power ( )

(iv) Coal ( )

(v) Biogas ( )

(vi) Others (Specify) ....

(vii)

18. If the source is fuel wood indicate where you obtain the fuel wood.

(i) Public Forest reserve ( )

(ii) Planted trees ( )

(iii) Virgin land ( )

(iv) Trees left in the farmland ( )

(v) Private forest reserve ( )

(vi) Fallow areas ( )

(vii) Neighbor's village land ( )

(viii) Sellers/vendors ( )

19. How do you manage firewood scarcity?

(i) Spend more time and/or labour in collection of wood ( )

(ii) Resort to less preferred species ( )

(iii)Cook more efficiently ( )

(iv)Cook less meals ( )

(v) Use more substitutes for wood ( )

(vi)Buy wood ( )

(vii) Plant trees(woodlots, trees on compound) ( )

(viii) Cut live wood ( )

0. What was the distance to the source of fuel wood in 10 years ago? (Kms)

....

1. What is the distance now to the fuel-wood source? (kms)

....

....

2. How long does it take to search fuel wood from the source to home place? (hrs)

....

....

3. Average number of fuel wood bundles and or bags of charcoal used per month

....

....

4. Who is responsible for energy availability in your household;

(i) Wife ( )

(ii) Husband ( )

(iii) Children ( )

(iv) Wife and children ( )

(v) Husband and children ( )

24. How do you rank the problem of fuel wood shortage in your area?

(i) Serious ( )

(ii) Moderate ( )

(iii) Small ( )

25. What do you think is the best strategy toward solving the problem of fuel wood?

(i) Migrate to an area closer to the source of fuel wood ( )

(ii) Plant trees ( )

(iii) Stop free range cattle, goats an ( )

(iv) Stop charcoal making ( )

(v) Prevent bush fires ( )

(vi) Looking for alternative sources of energy ( )

(vii) Others (specify). ....

26. Do you know any alternative energy other than fire wood and charcoal?

(i) Yes ( )

(ii) No ( )

27. If Yes, mention them;

(i) ....

(ii) ....

28. For the alternative energy sources you mentioned above, which ones do you use?

(i) ....

(ii) ....

PART 3: Assessment of biogas feasibility indicators in Warr Sub County

A. Awareness

29. Have you ever heard about the biogas technology?

(i) Yes ( )

(ii) No ( )

30. Have you adopted biogas technology?

(i) Yes ( )

(ii) No ( )

31. Who gave you information about biogas technology for the 1^{st} time?

(i) Biogas researcher ( )

(ii) Extension officers ( )

(iii) Politician ( )

(iv) Neighbor, Relative, friend who adopted BT ( )

(v) Biogas Project staff ( )

(vi) Others (Specify) ....

32. If you have not adopted biogas technology give reasons;

(i) Do not see the benefit of biogas technology ( )

(ii) Shortage of household labor ( )

(iii) Plenty of fuel wood in the area am living ( )

(iv) High Technology costs ( )

(v) Not aware of the technology ( )

(vi) I find it not appropriate ( )

(vii) Others (specify)..

B: Attitude towards Biogas Technology

33 What is your comment concerning biogas technology as alternative energy source;

(i) Is Appropriate technology ( )

(ii) Is Not appropriate technology ( )

34. What is your recommendation on biogas technology promotion?

1. Strongly recommended ( ) 2. Moderately recommended ( )

3. Not recommended .... ( )

35. Circle one number based on whether you strongly agree (SA), Agree (A), undecided (UD), Disagree (DA) or strongly disagree (SD) statement.

STATEMENT	SA	A	UD	DA	SD
• Biogas will solve the problem of fuel wood for cooking.	5	4	3	2	1
• Biogas technology will help to improve soil fertility.	5	4	3	2	1
• Biogas technology help to improve hygiene due to the use of wastes	5	4	3	2	1
• Biogas technology will reduce the rate of deforestation.	5	4	3	2	1
• Biogas will relieve women workload and save time used for fuel wood collections.	5	4	3	2	1
• Generally benefits of Biogas technology over weighs limitation/weakness.	5	4	3	2	1
• Government and other stakeholders have not sufficiently promoted biogas technology	5	4	3	2	1

36. If you are given a total of Ugsh 3m/= what will be your priority of investing?

(i) Invest in biogas technology ( )

(ii) Invest in other more paying enterprises ( )

(iii) Meeting households needs ( )

(iv) Others (specify) ....

37. If you will invest in other enterprises than biogas technology, rank such enterprises in order of importance

Enterprises	Rank 1 = most important
Farm production	
Livestock production	
Petty businesses	
Others (Specify)	