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ANALYSIS OF SOCIO-ECONOMIC, FACTORS INFLUENCING ADOPTION OF BIOGAS TECHNOLOGY AMONG FARM HOUSEHOLDS IN NORTH RIFT REGION, KENYA

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ABSTRACT

Biomass is one of the main sources of energy in Kenya accounting for over 68% of the total primary energy consumption. The continued dependency on biomass energy has resulted to land degradation, deforestation, drought and famine. The adoption and continued use of biogas energy technologies within the developed and developing countries is of great social, economic and environmental benefit. Although the positive benefits of using biogas is clear, in Africa and Kenya the households' biogas adoption level is low. The main purpose of this study was to analyze social, economic factors that influence adoption of biogas energy among farm households in Nandi, Uasin-Gishu and Trans-Nzoia counties in North Rift region of Kenya. The target population was all the farm households in the three counties. The study employed farm household multistage research design mainly cluster, and simple random sampling techniques to get a sample size of 295 respondents for the study. Farm households were used as units for analysis. Data was collected using questionnaires and analyzed using descriptive and inferential statistics. Logit model was used to estimate the parameters of the regression model. The results indicated that: social-economic factors were significant determinants of adoption of biogas technology (p – value $0.0000 < 0.05$) for all variables in North Rift region of Kenya. From the study findings, the following recommendations are drawn: Firstly government and other stakeholders should design policies that encourage the use of sustainable energy sources such as biogas. Secondly, incentives and provision of subsidies in terms of financial support should be given to households to acquire biogas devices. Thirdly households should be educated on benefits of using biogas. Government should also ensure efficient extension services in the study area by organizing workshops, trainings and make provisions to facilitate extension personnel involved in biogas adoption programs.

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1.1 Background to the Study

The exact status of biogas as a major source of energy is still a major challenge. It is only estimated that globally biogas production stands at 30 -40 billion m³ biomethane equivalent, to 1080 – 1440 PJ (IEA, 2013). The global data indicates that there is still room for expansion of biogas production that would save high dependability on petroleum products and forest as source of energy.

1.1.1 Biogas Use in the United States Studies have shown that there are over 2,200 sites producing biogas in the United States of America (USA). Out of this number, 191 are biodegradable (anaerobic) digesters run on farm materials such as cow dung and crop wastes. Approximately 1,500 anaerobic digesters use waste water treatment plants. It is estimated that 250 of the firms in the United States use biogas they produce as source of energy, in addition there are 576 landfill biogas gas projects. By comparison, Europe is still leading in biogas production with over 10,000 operating digesters http://www.americanbiogascouncil.org/pdf/biogas101.pdf accessed on 15th January 2014.

1.1.2 Biogas use in Europe: The European member states have laid major emphasis on the use of renewable energies, to be actualized by 2020. This will not only produce sustainable energy but also to assist in waste management. By 2010, Europe had managed to produce 21.1 billio M^3 biogas and 12.7 billion M^3 biomethane (IEA, 2012).

By 2011, electricity produced from biogas alone was 35.9 Thousand Watts per hour (here after TWh) and heat sales to factories was estimated at 16%. http://www.eurobserv-er.org/pdf/baro212biogas.pdf accessed on 15th January 2014. This is a clear indication that biogas is an alternative source of energy to both industries and households.

1.1.3 Biogas Use in Sweden: In Sweden, the use of biogas has gone beyond domestic consumption and has made the country the world leader in the use of biogas in the transport sector. In 2012 there were nearly 44,000 vehicles that were using biogas as source of energy in Sweden out of which 1800 buses, 600 trucks and the rest 41,600 were cars and light transport vehicles. Compared to the end of 2011 (one year later), the number of gas vehicles increased by about 14% (ES, 2012). Over a similar period of time, the number of upgrading plants has reached 47 plants, representing a 22% growth in biogas digesters since 2008.

1.1.4 China: Leader in Household Biogas Plants: In China, the renewable energy policy is similar to those in Sweden and Europe where biogas is currently playing a major role as an alternative source of energy. The available studies have shown a tremendous move towards the use of biogas. By 2013, there were nearly 42 million small biogas digesters in operation, producing biogas for households' domestic use, and a further 60,000 small, medium and large scale installations producing biogas for industrial purposes (Tong, 2013). Total biogas output in 2010 was estimated at 15 billion m³ biogas, equivalent to 9 billion m³ biomethane. China has put in place ambitious plan towards biogas energy and it is estimated that by the year 2020, there will be 10,000 agricultural biogas projects, 6,000 new industrial biogas projects with capacity to generate 3000 MW Total biogas output. The target is also to produce 50 billion M^3 biogas by 2020 (Beijing and Raninge, 2011). This clearly indicates that the country is moving towards cheap source of energy and waste management. This clearly shows China's commitment to disseminate biogas and make it a standard practice in households with estimated 8 million anaerobic digesters (IEA, 2002).

1.1.5 Biogas Use in Developing Countries: The benefit associated with biogas technology has been known for a long time unfortunately the implementation has been a challenge to many developing countries. In recent years, interest has increased due to the high costs of energy and the rapid depletion of fossil fuels and their environmental shortcomings. Worldwide, about 16 million households use small-scale biogas digesters (Ren, 2005). In developing countries, small-scale anaerobic digesters are used to meet the heating and cooking needs of individual rural communities (Amigun, Sigamoney, Blottnitz, 2008). The technology continues to be used successfully in Asia, Latin America and some regions of West Africa such as Ghana and Nigeria.

The development of large-scale anaerobic digestion or biogas technology in Eastern Africa is still at an embryonic stage but the potential is promising. Uganda, Rwanda and Kenya are the few pioneers in Eastern African countries (Amigun *et al.*, 2008).

In most developing countries, biomass-based energy accounts for more than 90% of all household energy consumption (FAO, 2014, 2013; 2012; and 2011). The dependence of the world's population on biomass fuels for domestic energy consumption has had a negative impact on the social well-being and has caused environmental degradation in most developing countries (United Nations, 2009; Inayat, 2011; Achard, Eva, Stibig, Mayaux, Gallego, Richards and Malingreau, 2002). The increase in global energy consumption over the next generation is expected to take place in the developing countries (United Nations, 2009). Biomass energy use is not only likely to contribute to global climate change, but could also give rise to other negative impacts. One of the possible impacts of biomass energy use is local air pollution, which has been a serious problem in the world's mega-cities for decades. Austin (2003) noted that this could be linked to fossil fuel combustion.

1.1.6 Biogas Use in African Countries: According to Africa Energy Policy Research Network (2004), energy is a key factor for economic and social development. Worldwide, more than two billion people lack access to sustainable and modern energy technologies (Amigun, Sigamoney and von Blottnitz, 2008). The energy sector in African is undergoing major reforms and institutional roles are shifting with new players entering the energy market. The private sector is increasingly taking over the role of energy service provision from the government whose role is expected to become more facilitative and regulatory. On the other hand, Africa is suffering from abject poverty in terms of modern energy saving technologies (Todaro, 2014). In order to develop and evade economic marginalization, Africa needs to increase not only total modern energy consumption but also the total number of consumers accessing these services.

The key challenge facing African energy sector is lack of provision of modern green energy technologies to over 60% of its population. To facilitate economic development and poverty reduction calls for modern sustainable energy sources (Jingura and Matengaifa, 2008). A significant proportion of African population lives in rural and peri-urban areas where access to modern energy is a major challenge (Nabuna and Okure, 2004). Majority of households rely predominantly on traditional sources of energy such as biomass fuels where wood fuel accounts for about 65% of the total primary energy consumption in the region (Nyang, 1999). Energy poverty is now emerging among rapidly growing proportion of the poor urban dwellers (World Bank, 2000; World Bank, 2001).

Rwiza (2009) explains invention and diffusion of biogas energy technologies in developing countries is one of the strategies perceived as instrumental in combating the negative effects related to the use of traditional energy sources particularly firewood and charcoal. According to Rwiza (2009) energy needs of the developing world have to be met in a sustainable manner. There have been several green energy technology programs facilitated and implemented for communities in different parts of the world with support from respective governments, Non-governmental organizations, scientific institutions and funding agencies, for more than five decades (Reddy, 2008). MDG's and sustainable development framework sees energy as an input to other development priorities. Expanded access to green energy technologies is an essential prerequisite to meeting all of the MDGs.

1.1.7 Biogas Use in Kenya: In Kenya the three main sources of energy are: petroleum, electricity and wood fuel/biomass fuels that accounts for 21%, 9% and 70%, respectively, of total energy consumption (Government of Kenya, 2004). Alternative renewable energy is also becoming important although it is still insignificant in the country's overall energy mix. Petroleum fuels are the most important sources of commercial energy in Kenya and are mainly used in the transport, commercial and industrial sectors. The country relies entirely on imported petroleum products, which accounted for about 16% of the total import bill in 2012 and consumed about 31% of the country's foreign exchange earnings from merchandise exports (Government of Kenya 2013; Mwakubo, Mutua, Ikiara and Aligua, 2007). Consumption of petroleum products was 2.4 million metric tonnes, with a per capita consumption of 76.2 kg. Projected growth with anticipated economic recovery is about 2% per annum (Government of Kenya, 2004).

Kenya's energy consumption is typical of developing countries, depends more heavily on biomass, mainly primary wood, charcoal, crop residues (Nyang, 1999). Household energy use, which constitutes 70%–75% of total Kenyan energy consumption, is dominated by the use of these biomass fuel (Nyang, 1999). In fact, wood is the most widely used fuel in Kenya, accounting for nearly 68% of the country's total energy supply (Nyang, 1999). The importance of biomass in the Kenyan economy is further illustrated by the rising demand, estimated to have increased from 27.8 million tons of oil equivalent (TOE) in 1988 to 35.3 million TOE in 1993. Wood is used primarily for cooking and also serves limited lighting purposes. Unfortunately, this energy source is not being used efficiently: Pyrotic conversion of wood to charcoal is only 15% – 25% efficient (typically transported to and then used in urban areas), and the three stone fires used in rural areas also suffer from very low efficiencies of 5% – 20% (Arnold, 2003).

Renewable energy resources include biogas energy, windmills, power alcohol, biogas, energy saving stoves and PV bulbs. Programmes for their increased development and use have been formulated and are intended to supplement and conserve, where appropriate, other major sources of energy. Since they are renewable, these sources of energy have the potential to contribute to social, economic and environmental dimensions of sustainable development (Akinbami, Ilori, Oyebisi, Oyebisi and Adeoti, 2001). The contribution, however, could be significant in the years ahead if appropriate strategies are put in place. Kenya has great potential for use of biogas energy throughout the year because of her possible anaerobic decomposition of livestock wastes (dung, urine and waste feeds). On average, the country could receive 4-6 kW/M2/day of biogas energy (or 1.54 billion tonnes of oil equivalent).

1.1.8 Biogas Energy use at Household Level

Use of improved energy technologies in Kenya has often been unsuccessful. Most households do not adopt the technologies at all, and if they do, use them in ways that do not achieve the reduction in wood fuel use and harmful emissions (Barnes *et al.*, 1994). It can be argued that the challenge of ensuring successful uptake and proper use of improved energy technologies -such as biogas, in rural households stems from the twin failure of adoption and implementation (Barnes *et al.*, 1994). Technology is not only the

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equipment, but also the knowledge required to fund, manufacture, operate and maintain the equipment, while transfer is the process of converting the concept of the technology into a sustainable framework that is understandable to the local people (Wilkins, 2002). Adoption in this context refers to the decision to acquire the new technology, while implementation refers to the households' actual use of the new technology (Klein and Knight, 2005). These failures in turn stems from a misunderstanding of households' decision making processes around improved technology adoption which are grounded in the livelihoods of the people, the social, political, cultural, economic and ecological dimensions of energy security, as well as access to alternative sources of energy to meet energy supply and demand (Barnes *et al.*, 1994). Biogas technology uptake and use in rural Kenya could be limited by some or all of these factors. It was the interest of this study to investigate these factors.

1.2. Statement of the Problem: Lack of access to clean sources of energy by households is a major impediment to development through health related complications such as increased respiratory infections and air pollution. The type of cooking fuel or lighting fuel used by households is related to the socio-economic status of households (Nyang 1999). Globally about 2.5 billion people (KNBS, 2013) rely on biomass such as fuel-wood, charcoal, agricultural waste and animal dung to meet their energy needs for cooking.

Table 1.1 Shows the main types of energy used by household in North Rift region of Kenya in percentage.

County	Electricity	Paraffin	LPG	Biogas	Firewood	Charcoal	Solar	Others
Nandi	0.2	1.1	0.5	0.3	89.1	8.4	0.0	0.1
Trans Nzoia	0.3	3.9	0.9	0.5	75	19.1	0.0	0.2
Uasin Gishu	0.7	7	5	0.8	54	31.5	0.0	0.3

Source: KNBS, 2013

North Rift's energy consumption is typical of Kenyan setting, depending heavily on primary wood, charcoal. The long term effect of this kind of dependency would lead to wood loss, resulting in deforestation and land degradation in North Rift region.

Despite its potential, the contribution of biogas to national energy supply is minimal, with less than 1.2% of households using it for cooking and water heating.

Biogas as an alternative source of energy could be safer and friendlier to the households and environment as a stop gap measure to climate change and as a control to the surging demand for energy that currently exceeds its supply.

It is in the light of these challenges that this study examines the social, economic, institutional, and technological factors influencing the adoption and sustainable use of biogas energy in the North Rift Region of Kenya.

1.3.1 General Objective:

To analyse socio-economic, technological and institutional factors influencing adoption of biogas technology in North Rift Region of Kenya.

1.3.2 Specific Objectives

This study was guided by the following objectives:

To identify the socio-economic factors influencing adoption of biogas technology by households in North Rift region of Kenya.

1.4 Hypotheses of the Study

***H0*$_1$**: *Socio-Economic factors do not significantly influence the adoption of biogas technology by farm households in North Rift region of Kenya.*

2.1 Benefits of Using Biogas Technology: Studies have shown that biogas technology have a number of benefit (Austin G., 2003). Well-functioning biogas systems can yield a range of benefits for users, the society and the environment in general. These benefits include: Production of energy (heat, light, electricity); transformation of organic wastes into high-quality fertilizer; improvement of hygienic conditions through reduction of pathogens (Hall D., Rosillo-Calle F, deGroot P 1992). Kassenga G. R (1997) found that adoption of biogas reduced workload, mainly for women, in firewood collection and cooking. Kituyi E. (2002) biogas technology has positive environmental externalities through protection of soil, water, air and woody vegetation. Day D. L., Chen T. H., Anderson J.C., Steinberg M. P., (1990) biogas use has economic benefits to households through energy and additional savings on fuel expenditure. Batzias F. A., Sidras D. K., Spyrou E.K., (2004) explain that since cow-dung is used to produce biogas, slurry can be used as fertilizer substitution, and has been found to increase yields of crops.

2.6 Theoretical Framework: This study was based on the theory of adoption. Adoption rates are a function of the characteristics of the adopter. The expected benefits and the anticipated costs from the process of adoption vary across various industries and sectors, and also are influenced by market structure, consumer demand, and the power of suppliers. Expectations and anticipations change over time, yet since information diffuses through various sectors at different rates due to external market factors, expectations and anticipations also will vary. One possible logistic functional form that describes a Rogers' diffusion model is the Bass (1995) model, and is based on the simple conjecture that the first adopters of an innovation communicate to, interact with, and influence other potential adopters in subsequent periods.

3.1 Study Area: The study area was North Rift region. The North Rift region comprises of the following counties Uasin Gishu, Nandi, Trans-Nzoia, Elgeyo-Marakwet, West Pokot and Turkana (see Appendix V1 and VII). From the six counties Nandi, Uasin Gishu and Trans Nzoia counties were purposively chosen for the study. The region was chosen for the study because it is generally endowed with plenty of exotic cattle. In this region a number of farm households practice zero grazing that is conducive for production of larger quantities of cow dung being the major raw material for biogas production in this context.

3.2 Research Design: A cross-sectional farm household survey research design was used. This design was chosen because it allowed the researcher to examine the effects of the random independent variables on the dependent variable (adoption of biogas). In addition the design allowed the researcher to apply aspects of survey research to track adoption of biogas technology in the North Rift region. The design has the advantage of measurements being taken at one point in time, and of creating room for exploratory and descriptive data (Detels, McEwen, Beaglehole and Tanaka, 2004). It is also useful in examining the possibility of a relationship between the independent variables and adoption of biogas technology.

3.2.2 Sampling and Sample Size Determination: The sample size was based on the formula provided by Pindyck and Rubinfeld (1998). This formula is normally used when the population is greater than 10,000 households and was stated as follows;

$$N = \frac{Z^2 PQ}{e^2}$$

………………………………………………………………………….. (3.1)

Where: Z = Normal quartile for example for 95%

confidence interval, z = 1.96; P = % of non-adopters in the population; $Q = 1 - P$, e = Margin of error. The study assumed that P = 50% and e = 5% and computed sample size is also shown below:

$$N = \frac{(1.96)^2 \times (0.5)(0.5)}{(0.05)^2} = 384$$

The sample size based on the formula was 384 farm households. This was suitable and large enough to allow reasonable and accurate interpretation of the results for the study. This is within Kathuri and Pals (1993) recommendation that a sample size of 100 is adequate for survey study. This sample size ensured that main characteristics of the households were captured.

3.2.3 Sampling Procedure: The North Rift region consists of six counties namely Nandi, Uasin Gishu, Trans Nzoia, West Pokot, Elgeyo Marakwet and Turkana. Purposive sampling was used to select three counties namely Nandi, Uasin Gishu and Trans Nzoia for the study. The counties were selected because they are the main counties where intensive dairy farming is practiced and production of cow-dung is produced in North Rift region.

Proportionate sampling method was used to distribute the sample size 384 farm households amongst the selected counties.

Table 3.2 Distribution of the Sample Size per county

County	Households	Sampling Method
Nandi	154,073x0.00073=112	Proportionate
Trans Nzoia	170,117x0.00073=124	Proportionate
Uasin Gishu	202,291x0.00073=148	Proportionate
Total	384	

Source: Author's Computation, 2016

The three divisions per county were purposively sampled based on the population dairy animals that ensure high cow dung availability. The farm households number per county was obtained from KNBS 2015. The total household sample size per county was proportionately distributed to all divisions based on different proportions as shown in the tables.

3.2.5 Sources and Types of Data Collected: Data that was used in this study was collected from two sources. These were:

Primary Data and Types of Data Collected: Primary was obtained directly from the farm households sources of information. The data was collected from household heads or informed members of the household interviewed in this study. The information that was collected included off farm income in Kenya shillings, farm income in Kenya shillings., farm size in acres, cattle herd size, cost of technology, in Kenya shillings. age of the household head in years, education level of the household head, gender of household head, family size, size of biogas device, operability, quality of gas, access to extension services, membership to group and access to credit. Information was obtained through interviews and administration of well-structured questionnaires. Each questionnaire

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was sub-divided into sections in order tocapture the required information as attached in (appendix ii).

Secondary Data and Types of Data Collected: Secondary data was collected from sources that included books, economic surveys, World-Wide Web, statistical reports, scholarly journals, thesis and dissertations, bulletins, monthly and annual reports and Government publications such as respective Region's Development Plans reports from non-governmental organizations involved in biogas promotions. The secondary data was used to complement primary data. Secondary data collected included population, number of trained households and types of energy and level of use by households in North Rift region of Kenya.

3.3.2 Specification of Empirical Model: The generalized adoption model that was estimated was as follows;

$$Z_i = \alpha + \sum_{j=1}^{18} \alpha_k X_{i,k} + \varepsilon_k$$

………………………… (3.17)

In this model X_i represent independent variables that were postulated to influence adoption of biogas such as: X_1 = age of the respondent (in years); X_2 = Gender of the respondent (male or female) X_3 = Cattle herd size; X_4 = Farm income (in Ksh); X_5 = Off-farm income (in Ksh.); X_6 = Farm size (in acres); X_7 = Cost of technology (in Ksh); X_8 = Size of the device (in metres cubed); X_9 = Group membership; X_{10} = Operatability; X_{11} = Family size; X_{12} = Quality of gas; X_{13} = Education level of the respondent; X_{14} = Access to extension services; X_{15} = Access to credit.

The model $Ln\ (P_i/1-P_i)$ is the log-odds matrix denoting adoption or non-adoption of the technology and α_K are estimated structural coefficients which represent the intercept for $k=0$ and ε_k represent stochastic error term.

4.1 Descriptive Statistics with Mean-Comparison Test

The descriptive characteristics of the sampled respondents are grouped as continuous and categorical variables. This is to provide a better understanding of the influence of the variables on biogas adoption.

4.1.1 Summary of Continuous Variables.

The continuous variables are age of the households, household size, off farm income, farm income, total income; cattle herd size and household fuel expenditure.

Table 4.1.1 Mean Comparison Test of Continuous Variables

Variable		Mean		T-Test	P-Value
	Obs	Adopters	Non-adopters		
Age	295	47.3605	60	-18.0442	0.0000*
Cattle herd size	295	10.3061	3	6.0783	0.0000*
Farm income	295	1154987	70000	9.4486	0.0000*
Off-farm income	295	317666.7	50000	7.4062	0.0000*
Farm size	295	17.79	4.5	6.9437	0.0000*
Cost of biogas Device	295	96630.27	58000	6.1352	0.0000*
Family size	295	5.8707	4	13.3856	0.0000*

Source: Authors Data Analysis Results, 2015

The sources of income for the farm households in North Rift Region of Kenya were income from crops, livestock, labour, remittances. The main source of income for non-adopters and adopters were farm incomes and labour incomes. The non-adopters total farm incomes was Ksh 70,000.00 and for adopters it was Ksh 1,154,987. Labour income for non-adopters Ksh 50,000 and adopters Ksh 317,666.70. The total accumulated income from all sources was Ksh 1,539,992 for non-adopters and adopters Ksh 2,224,250. The study found that a unit of biogas device costs Khs 96,499.32. It can therefore be inferred that majority of the households in North Rift region Kenya have the financial capacity to adopt biogas technology.

The t-test indicated a significant difference in the levels of income between adopters and non-adopters for all sources of income. The t-test indicated that income from; crops, livestock, income from labour, and other incomes were

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significantly related to adoption of biogas technology (p – values 0.0000 < 0.05). There was no significant difference between adopters and non-adopters in terms of income from remittances (p – value 0.0791 > 0.05). However the results of the t-test cannot be used conclusively to address adoption and non-adoption of biogas technology because they do not show direction of causality. Therefore it was inferred that income was one of the important determinants biogas technology adoption. This conforms to other findings by Mose (2013) on adoption of pest management technologies and Saina (2014) on adoption of various dairy technologies.

Results indicated that there was negative and significant effect between age of adopters and non-adopters (p – value 0.0000 < 0.05). Results further indicated that when the household head age was above 60 years the chances of adoption was likely to be zero but when age was less than 60 the chances of adoption was 1. It also shows that there was positive and significant difference between adopters and non-adopters of biogas technology among households in North Rift region in terms of herd size. It can be inferred that the size of the herd determine the amount of cow dung produced which is the main input for biogas production.

There was also positive and significant difference between adopters and non-adopters in term of farm income and adoption biogas technology among households in North Rift region. It can be inferred that farm income determined the household ability to invest in biogas technology.

Similarly there was positive and significant difference between adopters and non-adopters in terms of off-farm income and adoption of biogas technology among households in North Rift region. Therefore it was inferred that off-farm income increased the likelihood of adoption of biogas because it increases the purchasing power of the households. This finding supports Fernandez-Cornejo (2007) who found that adoption of agricultural innovations that save managerial time was associated with higher off-farm income in USA.

There was also was positive and significant difference between adopters and non adopters in terms of farm size and adoption of biogas technology among households in North Rift region. Therefore it was inferred that farm size increased the likelihood of adoption of biogas because it influences the size of the herd the household can keep.

The positive and significant difference in terms of cost of technology among adopters and non-adopters of biogas cannot be interpreted. This is because cost of technology is likely to influence direction of adoption.

There was also positive and significant difference between adopters and non-adopters in terms of family size and adoption of biogas technology among households in North Rift region. Therefore it was inferred that the larger the family size the higher the demand for energy by the household. This influences adoption of biogas as alternative source of fuel. Family size also plays a major role in provision of labour that may be required in maintaining biogas devices.

4.3 Land Size and Pattern of Use with Mean-Comparison Test: The summarized statistics of land size and pattern of use with t-test for mean comparison test between adopters and non-adopters are presented in table 4.1. The t-test indicated a significant difference in the land size and pattern of use between adopters and non-adopters for land size, land under crop, leased land, total land size land under trees and land under non-agricultural use (p – values 0.0000 < 0.05) in North Rift region. Therefore based on these results it was inferred that land size and pattern of use was one of the important determinants of biogas technology adoption.

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Table 4.1 Land Size and Pattern of use with Mean-Comparison Test

Category of Land	Mean			
Land Use Pattern	Non-Adopters	Adopters	T-test	Sig.
Land Size	8.5	15.91	4.2147	0.0000*
Land under Crops	6.5	10.21	2.9664	0.0016*
Leased Land	0.0	2.1139	3.4835	0.0003*
Total Farm Size	4.5	17.79	6.9437	0.0000*
Land under Trees	1.0	1.9514	4.5929	0.0000*
Non-agricultural use	0.0	2.7829	10.3566	0.0000*

(*) Indicate that the mean- comparison test is significant at 5% level
Source: Author's Computation, 2015

4.5 Characterization of Energy Sources and Expenditure

Table 4.5.1 Family Fuel Expenditure Pattern

Type of Fuel	Mean (KSh)	Std. Dev.	Min	Max
Charcoal	5,075.088	31135.28	0	470000
Firewood	4,854.333	13557.35	0	180000
Kerosene	721.3559	2580.513	0	36000
Electricity	9,214.712	28960.29	0	420000
LPG	1,912.475	5880.017	0	43200
Agricultural Residual	508.1153	3735.098	0	57900
Other	557.9797	5155.815	0	74000

Source: Data Analysis Results, 2015

The study characterized the energy sources and expenditure incurred by households in North Rift region Kenya (Table 4.3.1). The study found that the three major sources of energy with high mean expenditure in this region were electricity Ksh 9,214.712, charcoal Ksh 5,075.088 followed by firewood Ksh 4,854.333. The use of firewood and charcoal as energy sources for cooking is still predominant, an issue the study was mainly concerned with because of their impact on the environment.

4.6.1. Family Fuel Expenditure Pattern with Mean-Comparison Test

The summarized statistics of family fuel expenditure pattern with t-test for mean comparison test between adopters and non adopters are presented in table 4.3.3.The t-test indicated a significant difference in expenditure on charcoal, firewood, kerosene, electricity, LPG, agricultural residues and other fuel sources. An interesting and significant result was that non adopters were spending more on kerosene. The sampled households had zero expenditure on charcoal, firewood agricultural residues and other sources. This was an indication that households got energy sources like fire wood freely from their farms or nearest public forest. The zero expenditure on electricity and LPG was an indication that some household were not connected to electricity and were not using LPG as source of energy.

Table 4.6.1 Family Fuel Expenditure Pattern with Mean-Comparison Test

Type of Fuel	Mean			
	Non-Adopters	Adopters	T-test	Sig.
Charcoal	0	5088	2.800	0.0027*
Firewood	0	4871	6.1500	0.0000*
Kerosene	3600	711.5645	-19.160	0.0000*
Electricity	0	9205.238	-1.652	0.0498*
LPG	0	1878.163	-29.466	0.0000*
Agricultural residual	0	509.843	2.337	0.0101*
Other	0	559.8776	1.859	0.0320*

(*) Indicate that the mean- comparison difference is significant at 5% level

Source: Author's Computation, 2015

4.7.1 Characterization of Energy Sources

Table 4.7.1 Characterization of Energy Sources

Joint Tests		Value	Df	Probability
Max |z| (at period 2)*		4.974117	292	0.0000
Individual Tests	Var. Ratio	Std. Error	z-Statistic	Probability
Charcoal	0.499101	0.100701	-4.974117	0.0000
Firewood	0.355402	0.167301	-3.852928	0.0001
Kerosene	0.166687	0.239930	-3.473145	0.0005
Electricity	0.090896	0.323102	-2.813675	0.0049

Source: Data Analysis Results, 2015

The study characterized the energy sources and use by households in the North Rift region of Kenya (table 4.8). The results showed that variance ratios were all significant (p – values 0.0000, 0.0000, 0.0005 and 0.0049 all < 0.05). Therefore it was concluded that use of different fuel sources were significantly related. It can be inferred that to address a specific source of energy requires addressing all sources jointly. The use of firewood as source of fuel is still predominant an issue the study was mainly concerned with because of its effect on the environment.

4.7.3 Logit Regression

Table 4.7.3 Logit Model Regression Results for Adoption of Biogas Technology

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	-4.15E-16	5.80E-16	-0.715395	0.4750
Age of the respondent	-3.12E-17	5.19E-18	-6.002790	0.0000
Gender of Respondent	-4.26E-16	8.79E-17	-4.843075	0.0000
Cattle Herd Size	3.39E-15	3.56E-16	9.524568	0.0000
Farm Income	5.23E-17	2.52E-17	2.072151	0.0392
Off-Farm Income	1.18E-21	5.27E-22	2.236318	0.0262

Farm Size	3.51E-18	1.40E-18	2.516243	0.0125
Family Size	-2.25E-19	7.74E-20	-2.901012	0.0040
Education Level	1.000000	1.19E-16	8.38E+15	0.0000
R-squared	0.946743	Mean dependent var		0.843003
Adjusted R-squared	0.946522	S.D. dependent var		0.485326
S.E. of regression	9.16E-16	Sum squared resid		2.19E-28
F-statistic	2.64E+30	Durbin-Watson stat		1.627060
Prob. (F-statistic)	0.000000			

Source: Author's Computation, 2015

Regression results are presented in Table 4.5.3. The social factors such as age, education level of the respondent household size and gender significantly determined adoption of biogas technology by farmers in North Rift, Kenya. Age had negative and significant effect on adoption of biogas (p – value 0.0000 < 0.05). This led to rejection of first hypothesis. Therefore it can be inferred that as the age increases the likelihood of adoption decreases. This findings support prior studies by Mishra (2010) who pointed out an inverse relationship between age and adoption.

Education level of the household head was positive and significant (p – value 0.0000 < 0.05). Education enhances one's ability to receive, decode and understand information related to adoption of a new technology. This finding conforms to previous studies (Slberman, Just and Feder 1985; Hojo, 2002; Mishra, 2010 and Melese, 2015).

The size of the family had positive and significant effect on adoption of biogas by households in North Rift region (p – value 0.0040 < 0.05). The variable was expected to influence technology adoption positively. The family size is an important socio-economic characteristic because it often determines how much family labour the family requires in the construction and maintenance of biogas devices. It also determines the extent of energy demand by the households and the degree to which the household is able to respond to innovative change.

Gender had negative and significant effect on adoption of biogas by households in North Rift region (p – value 0.0000 < 0.05). Mwangi, Verkuji and Bisand (1999) found the adoption of new technologies was biased by gender, where female-headed households adopt the technologies less. This is contrary to the expectation that female headed households should support those technologies such as biogas as this addresses the issue of energy for cooking.

The result showed that economic factors such as cattle herd size, land size, income, and off-farm income significantly determined adoption of biogas technology by farmers in North Rift, Kenya (p – values 0.0000 < 0.05). Therefore the second hypothesis was rejected. These results were consistent with Srinivasan (2008) who observed that domestic biogas programs were often justified on the basis of the private benefits and costs accruing to the individual households.

The study analyzed if social factors such as age, education level of the respondent household size and gender significantly determined adoption of biogas technology by households in North Rift, Kenya. Results indicated that age had a negative and significant effect on adoption of biogas technology in North Rift region (p – value 0.0000 < 0.05). This is consistent with Quddus (2010), Quddus (2012), Feder *et al.*, (2001) and Saina (2014) who found that age was negatively related to technology adoption. This is because

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households tend to be tied up to the old cultures of doing things thus being rigid to new ideas. This can also be referred to as cultural lag in technology adoption. Socio-economic factors such farm size, land tenure, education, gender, age, off farm income, farm income, have no significant influence on the adoption of biogas technology in North Rift Region. The results indicated that socio factors such farm size, land tenure, education, gender, age, off farm income, farm income, have no significant influence on the adoption of biogas technology in North rift region.

4.7.4 Logistic Regression to Determine Log of Odds Ratio

The obtained results were then transformed through logistic regression to obtain the log of odds ratios presented in table 4.5.3. This was done to make interpretation easy. The log of odds showed that one unit change in cattle herd size increased the chance of adoption of biogas by a household by 9.07. The effect is the same as for group membership 9.69 that had the biggest effect on adoption of biogas. This implied that adoption of biogas by households can be enhanced by encouraging households to form groups, increasing size of herd and reducing the cost of technology.

Table 4.7.4 Logistic Regression Results for Adoption of Biogas Technology

Variable	Odds Ratio	Std. Error	t-Statistic	Prob.
Age of the respondent	2.03657	5.19E-18	-6.002790	0.0000
Gender of Respondent	1.58926	8.79E-17	-4.843075	0.0000
Cattle Herd Size	9.07489	3.56E-16	9.524568	0.0000
Farm Income	7.73331	2.52E-17	2.072151	0.0392
Off-Farm Income	2.46765	5.27E-22	2.236318	0.0262
Farm Size	5.09416	1.40E-18	2.516243	0.0125
Family Size	1.21717	7.74E-20	-2.901012	0.0040
Education Level	2.71828	1.19E-16	8.38E+15	0.0000
R-squared	0.946743	Mean dependent var		0.843003
Adjusted R-squared	0.946522	S.D. dependent var		0.485326
S.E. of regression	9.16E-16	Sum squared resid		2.19E-28
F-statistic	2.64E+30	Durbin-Watson stat		1.627060
Prob(F-statistic)	0.000000			

Source: Author's Computation, 2015

Binary logistic regression results indicated that age of the households had negative and significant influence on adoption of biogas by households. Further the odd ratio 2.04 indicates that as one advances in age the chances of adoption reduces by 2.04. These results are consistent with Igbal Anwar Akram and Irfan (2013).

The results of Binary logistic Model, indicates that gender of the households had negative and significant influence on adoption of biogas by households. Further the odd ratio indicates that a unit change in gender reduces the chances of adoption by 1.59 times. These results were in line with prior expectation because most of the respondents were female. It can inferred that biogas adoption was female agenda but male remained to be the decision makers. Programs should be designed to encourage male population to participate in energy provision for their households.

The results of Binary logistic Model, indicated that herd size had positive and significant influence on adoption of biogas by households. Further the odd ratio indicated that a unit change in herd size increased the chances of adoption by 9.07 times. These results were in line with prior expectation because herd size influences the amount of cow dung produced being a major raw material in the production of biogas. These results support prior studies (Iqbal *et al.,*) who found positive associated between number of livestock and adoption of the biogas in Punjab, Pakistan. Programs should be designed to encourage households to practice zero grazing and increase their herd size in order to obtain enough cow dung for biogas production.

Farm income of household head was found to be significant factor in the adoption of the biogas. Further the odd ratio indicated that a unit increase in farm income increased the chances of adoption of biogas by 7.73 times.

Off-farm income was positive and significant with odds ratio of 2.47. This indicates that a unit increase in off-farm income increased the likelihood of adoption by 2.47 times.

Size of Land was positively related to the adoption of the biogas. It was found that a unit increase in farm size supported the likelihood of adoption of biogas by 5.09 times. This is because large sizes of land allow the households to keep large number of livestock.

Education had significant and positive effect on adoption of biogas in comparison. The odd ratio disclosed that for one unit increase in education the chances of adoption of biogas improved by a factor 2.72 times. Therefore it was inferred that as education of the household head increases the trend of the adoption of the biogas also increases.

Family size was also noted to be negatively related to the adoption of the biogas. The odd ratio indicated that unit change in size of the family reduces the chances of adoption by 1.22 times. These results contradict Igbal (2013) who found positive association between family size and adoption of biogas in Punjab, Pakistan.

The study shows that socio-economic factors significantly influence biogas technology adoption in North Rift. Specifically, the probability of a household adopting biogas technology reduces with increase in age of head of household. The other factors that had positive and significant influence were size of land, number of cattle owned and household head education. Household income proved to be a key factor in influencing a household's decision to adopt biogas technology, it was also positively related to the adoption rate of biogas. The odd ratio of household head education tells us that as education increase adoption rate also increase. Family size was also found to be negatively associated with the adoption of the biogas. In conclusion all the covariates that were modeled influenced adoption of biogas in North Rift region.

5.2.6 Conclusions: This study showed that adoption of biogas technology in North Rift region was influenced by socio-economic factors. It also showed that technology adoption had a positive impact on farm house hold fuel expenditure hence impacting on living standards. The finding of the study was that income had a positive and significant effect on adoption of biogas technology.

The findings indicated that economic factors such as off-farm income, farm income, farm size and cattle herd size significantly influenced adoption of biogas technology by households in North Rift region. This was supported by p – values 0.0000 < 0.05. These findings support prior studies

(UNEP, 2012; Hamlin, 2012; Behanu, 2002; Kidane 2001; Gitonga, 1997; Green and Ng'onga'ola, 1993; and Legesse, 1992). It can therefore be inferred that the household economic status is a major factor in policy evaluation that are designed to improve the level of adoption of biogas technologies.

5.3 Policy Recommendations: The findings provide several policy implications for adoption and general decision making in energy sector. The results of the study suggests that energy providers should put emphasis on maintaining consistent and regular extension visits and contact with the users to accelerate adoption of biogas technology.
Energy providers should demonstrate their willingness to give regular education, training on precaution on use of biogas energy to avoid any negative effects that may arise from use of biogas technology. This was evident from the fact that biogas users who suffered injuries and property damages as a result of explosions could send negative information on the use of biogas device.

The study also recommends that energy providers should be facilitated financially by their organizations so that they can increase the coverage area. This will ensure that more households are exposed to biogas technology.
The researcher recommends that the ministry of energy should harmonize the policy on energy and environment so as to uphold biogas technology as an alternative clean green energy.
There is need for a central biogas coordinating body at the national and regional level to coordinate and monitor stakeholder roles as well as loans to households to enhance adoption of biogas as alternative source of sustainable energy.
The study found that most of the households still depend on firewood and charcoal as major sources of energy. This is likely to have a negative impact on forests thus leading to deforestation. It is recommended that Government and other stakeholders should design policies that encourage the use of sustainable and cheap energy sources such as biogas.
Access to credit had positive and significant effect on adoption of biogas. Therefore economic incentives such as financial support and provision of subsidies by government should be given to households to enable them acquire biogas devices.
Policies should be designed to address women who are affected in terms of energy demand for cooking and other household use by organizing seminars on biogas an alternative source of energy. Community leadership program and social network should be developed bynon-governmental organizations to enable continuous development of biogas plants without interruptions, and meet specific local circumstances of the households through participatory and establishment of demonstration centres, to promote adoption and use of renewable energy such as biogas.

5.4 Suggestions for Further Research: As a result of the limited scope of this study, some other determinants of adoption and impact of biogas on the livelihoods of farmers remain unknown. There is need for similar research to be replicated to cover larger geographical region so as to compare the results.
An analysis of economic impact of adoption of biogas technologies on gender basis and an examination of their possible contribution to gender equality and empowerment of women farmers would be useful in informing the decision on their low representation in farmers groups.
There is need for study to determine socio-economic factors that determine adoption of slurry as fertility enhancing input since this is a major byproduct of biogas.
Adoption of biogas technology save time in firewood gathering by households and money spend on other sources of energy. There is need for an impact analysis to determine the impact of adoption on farmer's expenditure pattern and time released for other economic activities.

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