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ENHANCING ENERGY ACCESS AND SOIL FERTILITY MANAGEMENT THROUGH BIOGAS TECHNOLOGY IN SMALLHOLDER DAIRY PRODUCTION SYSTEMS IN NYERI COUNTY, KENYA

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ABSTRACT

Despite availability of raw material from zero-grazing units, adoption of slurry powered biogas technology among smallholder dairy farmers in Mukurwe-ini, Nyeri County remains low. Not taking advantage of such alternative and renewable energy is undermining sustainable development goals by maintaining demand for wood fuel, its negative impacts notwithstanding. The purpose of this study was to show that the potential of biogas technology for enhancing environmental, health and income benefits to farmers is high, and therefore needs to be exploited. A survey study using questionnaires and key respondent interviews was used to collect data from 120 dairy farmers, randomly selected from an official sampling frame of 1204 households having zero-grazing units. Descriptive statistics was used for data analysis with focus on identifying general trends on opportunities and challenges of adopting biogas technology in the study area. Results indicated that the low adoption of about 36% was mainly attributed to high initial installation costs, lack of readily available credit facilities devoted to biogas development, and absence of locally trained biogas technicians. Dissemination of biogas technology was constraint by poor promotional strategies, inadequate operational funds and limited support from government. Establishing farmer-friendly biogas credit facilities and integrating biogas technology in National and County government climate change mitigation programmes would greatly enhance adoption and scaling-up of biogas technology within smallholder intensive dairy systems. This necessitates strategic partnerships involving farmers, public and private sectors, and non-governmental agencies; lubricated by the common goal of clean production and consumption patterns.

Keywords: Dairy Farming, Zero-grazing, Biogas, Kenya

1. INTRODUCTION

1.1 Background

Most households particularly in sub-Sahara Africa rely heavily on biomass energy such as firewood and charcoal to meet their various domestic energy demands and in particular cooking (Chirwa *et al*., 2008; Lattimore *et al.*, 2009; Kenya Integrated Household and Budget Survey 2009, Remedio, 2011). Such high demand of firewood is a threat to the national forest cover currently estimated at 6.9% (Republic of Kenya, 2014) against an international benchmark of 10% (Republic of Kenya, 2010). This calls for deliberate efforts to investment in planting new trees and preserving existing tree from various threats through energy alternatives. Some initiatives in this regard include provision of electric power through the rural electrification programme based on hydropower and geothermal technology (Rural Electrification Authority, 2009). For being expensive, majority rural households are unlikely to afford it, thus maintaining pressure on wood fuel and hence the negative environmental and health effects. Affordable alternative energy sources in the context of clean production mechanisms are thus critical in current and future research for development. With a wide variety of biodegradable raw materials, biogas becomes an obvious alternative. Experience elsewhere shows that any farmer with 1-3 dairy cows housed in a zero grazing unit can collect enough cow dung for biogas production (http://theorganicfarmer.org/Articles/choose-type-biogas-system-you-need).

1.2 Problem Statement

Although Mukurwe-ini is a high potential agro-ecological zone, with each farmer having 2-6 dairy cows under zero-grazing production systems, and thus guaranteed supply of raw material for biogas generation, less than 40% of households have adopted this technology (Wakulima Dairy Limited, 2011). Reliance on wood fuel will thus continue having negative environmental and health effects in the study area as illustrated in the conceptual framework in figure 1 below. To reverse this trend, the paper argues for increased adoption of biogas technology. This however depends on surmounting some key challenges in the dairy production system which, manifest as various socio-economic and environmental factors that influence farmers' decisions. Similarly to maximise the adoption of biogas technology in the study area, existing opportunities must be taken advantage of from various fronts.

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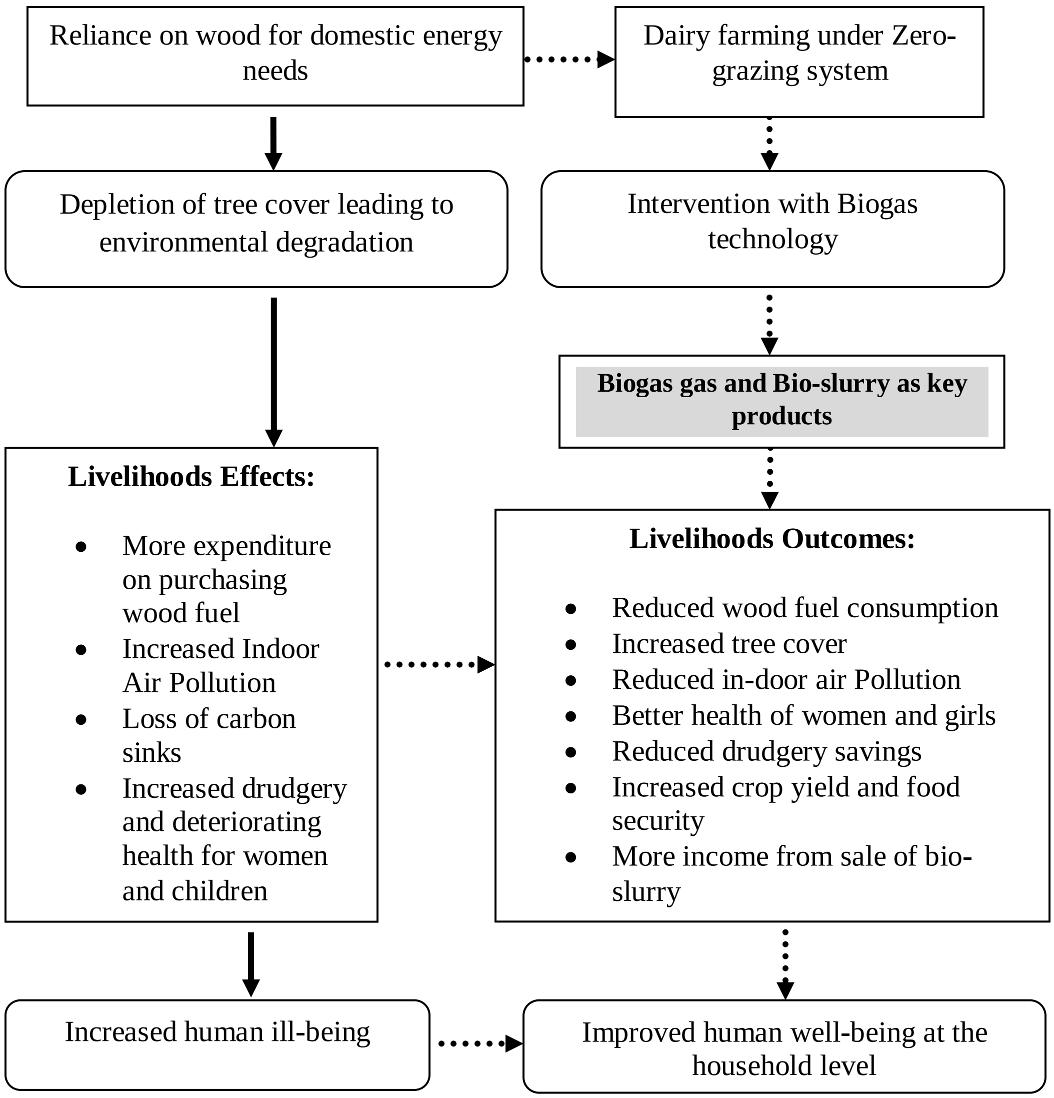

Figure 1: Relationship between wood fuel, zero-grazing and enhanced human well-being (the solid line represents the current and unwanted scenario while the dotted line represents the intended intervention)

1.3 Overall Objective

The overall objective of this study was therefore to assess the challenges and opportunities of scaling-up and scaling-out biogas technology in order to contribute to improved living standards of the households in the area and also to environmental recovery and management through reducing pressure on tree cover. In the long run, increased adoption of biogas at household levels would contribute to the realisation of clean production and consumption mechanisms as

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envisaged in the sustainable development goals nine and twelve (https://sustainabledevelopment.un.org/topics).

2. BRIEF LITERATURE REVIEW

Kenya was among the first countries in Africa to adopt biogas technology in the early 1950s. However, uptake remained low until the Kenya National Domestic Biogas Programme, which is part of Africa Biogas Partnership Programme was rolled out in 2010. Under the Kenya National Federation of Agricultural Producers as the implementing agency, the country constructed a total of 11,579 against a target of 11,690 biogas plants between year 2009 and 2013 (http://www.nation.co.ke/business/seedsofgold/A-biogas-digester-for-the-small-dairy-farmer/2301238-2908512-734ti0/index.html). Currently a $ 6.5-million biogas plant powered by corn waste is scheduled to generate 2.2 megawatts of electricity that will be connected to the Kenyan national grid (Renewable Energy World, 2015). The poor rural households may still not benefit much because of the cost factors associated with electricity. Biogas as the consumable product is what will benefit most rural households more. Although many biogas designs exist (GTZ, 2009), the technologies that people embrace and use play a fundamental role in shaping the efficiency, equity and environmental sustainability of natural resource management. These technologies would however be of little value unless they are judged to be appropriate by farmers and subsequently adopted.

Initial popularization of biogas in Kenya centred on the floating drum type (Indian digester) and the fixed dome type (Chinese digester). Although these systems have been successful in their countries of origin, adoption in Kenya has been minimal because of expensive installation costs estimated at more than KES 50,000 per unit in the early 2000s (Karanja & Kiruiro, 2003). As a response to the cost challenge, a cheaper model – the plastic tubular digester was introduced in Kenya in the 1990s and the adoption of the technology had increased over the years in different parts of the country (Karanja & Kiruiro, 2004). This type of digester is also popular in Vietnam because the materials used in construction are cheap and are locally available (Zhu, 2006).

Recently the International Fund for Agricultural Development has introduced a system called “flexibiogas”, a small bio-digester able to convert about 20kgs of cow manure into about 1,000 litres of gas. One hundred of these systems were scheduled to be installed in rural Kenya (https://www.rwlwater.com/kenya). To scale-up the technology within households calls for innovative ways of overcoming the initial invest costs. According to Njagi (2016), although biogas has an upfront cost, it becomes practically free once the equipment is installed. To afford it farmers are being facilitated with one-year loans for biogas units by the development agencies of the German and Japanese governments. To prevent a dependency syndrome, the Kenya government needs to take lead in such initiatives based on its energy policy.

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Biogas can be marketed or promoted as a multiple benefit energy source with potential to counter many adverse social, economic, health and environmental impacts connected with over reliance on firewood and charcoal (Tafdrup, 1995; Shell Foundation, 2007). The positive impact of biogas is demonstrated through the "eco-toilet projects," whose role as bio-centres continue to generate biogas that has improved the lives of people in slum settlements like Kibera in Nairobi (http://www.dw.com/en/world-toilet-day-kibera-slum-seeks-to-ground-flying-toilets). A typical bio-centre has toilets facilities, hot water bathroom powered by the biogas, a laundry facility, offices and even a conference facility that combined generate income for the residents through internal and external use. That biogas is being continuously generated from human waste means that with proper designs and planning, zero-grazing units can be modified to include biogas systems to power most rural households where dung is readily available like in the study area, ukurwe-ini.

While interest in using wastes from agricultural value chains for compost making is gaining momentum in mostly high potential areas in Kenya (KAPAP, 2015), a recent survey suggests that to accelerate commercialization of biogas technology in Kenya, Ethiopia and Tanzania, priority attention should be given to private sector development, quality management and affordability of plants (KENAFF, 2014). Private sector development is particularly important in Kenya due to its capital endowment and increasing role targeted extension service (Speranza *et al.*, 2009). Quality management on the other hand entails proper handling of requisite raw materials and putting in place mechanisms that ensure reliable supply of gas. Similarly, affordability is critical given the low income levels and general poverty within the rural households. Ultimately capacity building in the context of farmer-friendly biogas systems is what research should focus on. Outside of Kenya, the use of biogas is being extended to benefit more than a quarter of a million people in Ethiopia, Kenya, Tanzania, Uganda, and Burkina Faso by 2017 through the initiative of the Africa Biogas Partnership Programme (http://www.snv.org/project/africa-biogas-partnership-programme-abpp).

3. RESEARCH METHODOLOGY

3.1 Study area

This study was done in Mukurwe-ini sub-county in Nyeri, Kenya. The sub-county lies within latitude 36 ^{0} 34'' E and longitude 0^{o} 42'S. The climate is humid with an average annual rainfall of 1250-2500 mm, received twice in a year - long rains March to May, while short rains start in October and end in December (Jaetzold & Schmidt, 2007). The rainfall and mean annual temperature of 25^{o}C provide ideal conditions for active microbial activity within biodegradable materials. The majority of land users in the sub-county are small-scale mixed farmers with dairy farming under zero-grazing systems as a major occupation. Milk is thus a key source of income

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(Wakulima Dairy Limited, 2011). The area's hilly topography also favours biogas technology as it would ease flow of the slurry to the point of application away from the digesters (Marchaim, 1992). The population of Mukurwe-ini was 83,932 people in 2009, with a density 470 persons per km^2 and an annual increase of 2.6 % (KNBS, 2010). Coupled with high dependence on wood fuel, deforestation and other forms of environmental degradation remain key threats to the area's environmental health and subsequent human well-being (Mukurwe-ini Constituency Strategic Plan, 2012-2017). Energy alternatives remain priority investment areas for county development.

3.2 Data Collection and Analysis Methods

Since the intention of this study was to determine general trends, a descriptive survey design as explained by Handrick *et al.*, (1993) was used in data collection. Simple random sampling was used to select 120 respondents from a target population of 1204 households obtained from a registry of dairy farmers under the banner of Wakulima Dairy Group limited. With the help of a few trained enumerators, a self administered questionnaire was used to collect information from these actual respondents at their farms, the unit of analysis being a dairy farming household. Purposive sampling was used to identify key informants from the relevant Community Based Organization, contact farmers, line Ministries and farmers' Self-Help Groups. Consensus on emerging opinions was cross-checked through use of focus group discussions and expert opinion from key informants from both public and private biogas promoters. Availability of digesters within households and status of the biophysical environment was determined through observations and use of environmental checklists designed for that purpose. The area was criss-crossed for such spatial survey following natural transects and systematic sampling that led the researcher to households that were interviewed. Collected data was cleaned, coded, entered in to SPSS spreadsheet and subjected to descriptive statistical analysis. Content analysis was used to manage and make sense of interview-based data.

4. RESULTS AND DISCUSSIONS

4.1 Household Energy Sources and Relative Importance

That up to 75% of the sampled population relied on dairy farming for their livelihood (Figure 2), which was indicative of the potential of scaling-out biogas technology in the County. The challenge to such farmers who have embraced zero-grazing mainly for milk production is how to extend the benefits to include clean energy inherent in the system. Results further showed that on average, each household had 3 dairy cows and a calf under zero-grazing system, a number that is considered adequate in supplying raw material capable of satisfying cooking needs of a family (Schwengels, 2009).

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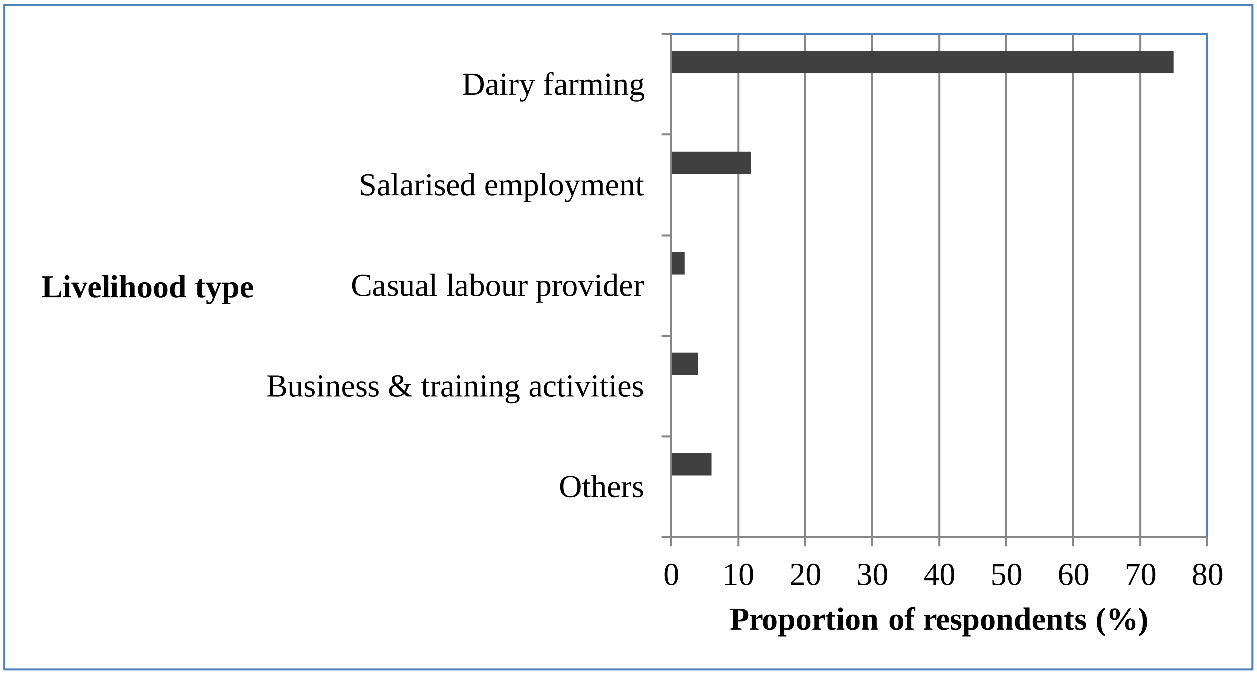

Figure 2: Percent proportion of respondents in various livelihood engagements

Compared to a study by Muradin & Foltynowicz (2014) where two mature cattle were considered adequate for a digester to produce biogas of 1400 litres daily, an amount considered enough for fuel energy needed by a family of 6 persons, with three cows and a calf, Mukurwe-ini farmers would have no shortage of raw material. That 76% of the households relied on wood fuel as their primary source of cooking energy is indicative of the expenses associated with cleaner sources like electricity, Gas and kerosene (Figure 3). Nationally only about 4% of rural population has been connected to the national electricity grid (Rural Electrification Authority, 2009). Although efficiency when using wood fuel can be enhanced through use of improved cook stoves as demonstrated by among others World Vision Kenya in Baringo and Nakuru (World Vision-Kenya, 2016), biogas may be the solution to energy shortages due to the readily available raw material from the zero-grazing units in Mukurwe-ini.

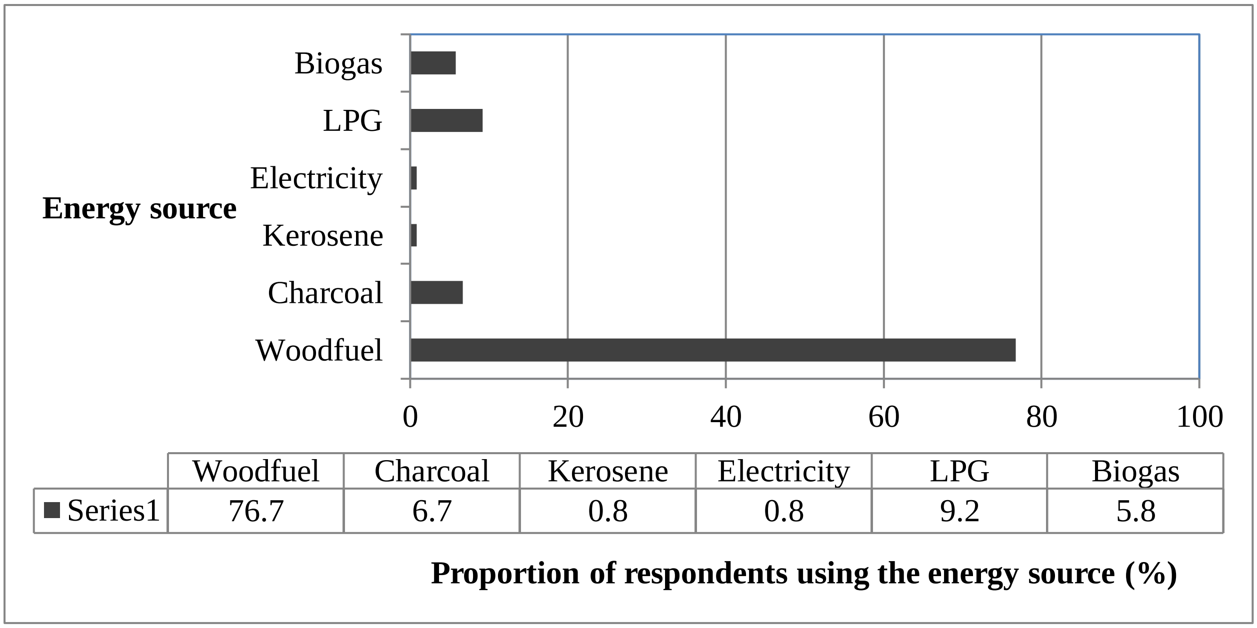

Figure 3: Sources of cooking energy among the respondents in Mukurwe-ini

In the absence of biogas, more than 70% of households relied on wood fuel as the choice source of energy. The proportion of respondents using wood fuel to complement biogas was about 30% (Figure 4). The use of charcoal was also on the decline with only 4.7 % of the respondents with biogas energy using it as their main source of cooking energy compared to 7.9% of those respondents without biogas facilities. By implication, alternative energy sources reduce the pressure on wood fuel, thus positioning the community to reap other benefits of increased tree cover such as carbon sequestration, environmental aesthetics, biodiversity conservation and reduced land degradation.

Similarly, the amount of wood consumed per day was lower by 40% for the group of women using biogas digesters (average consumption of 14 lbs/day) compared to the referent group (25 lbs/day). These findings are similar to those obtained Dahoo (2011) on the impacts of bio-digesters on Kenyan farm women. Accordingly, aggressive popularization of biogas has potential to increase its adoption and consequently contribute to efforts of reducing drudgery on the part of women when it comes to household chores including fetching firewood.

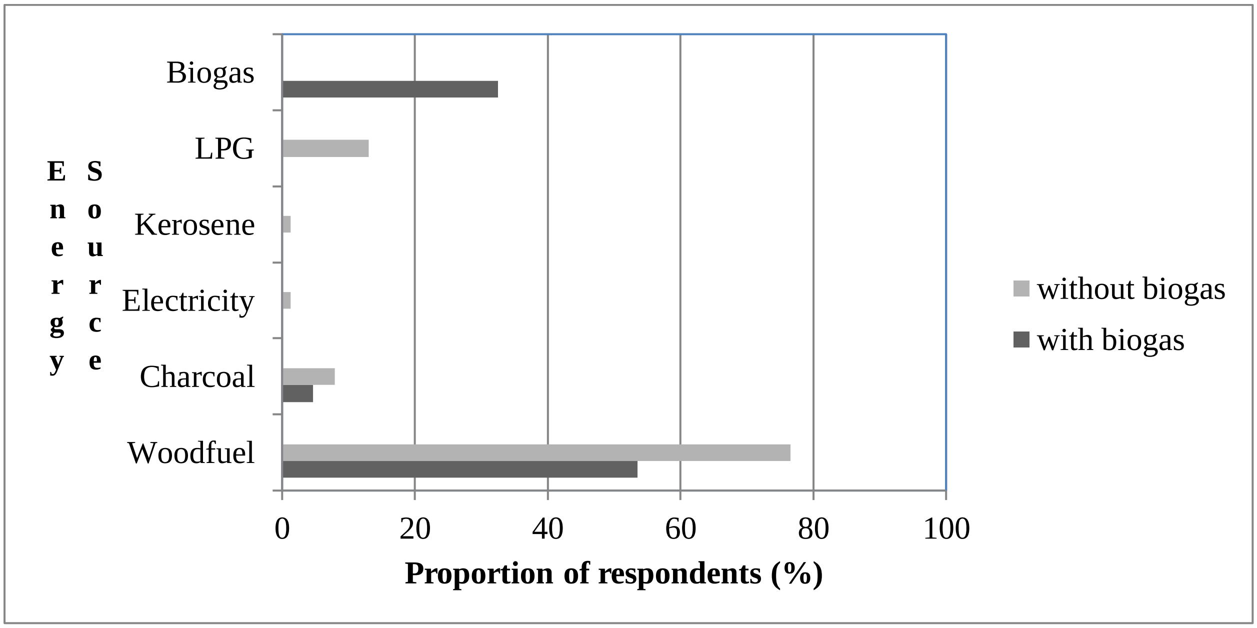

Figure 4: Types of cooking energy for households with biogas and without digesters (%)

4.2 Status of Biogas Technology

Overall about 35.8 % of the dairy farmers in the study area had adopted at least a biogas plant at the household level. In terms of design, the plastic tubular digester was more popular with 72% of respondents. This popularity was attributed to the lower costs incurred in installation, unlike the masonry types such as floating drum and fixed dome that are capital intensive. This means that if the cost of installing the floating drum and fixed dome digesters is lowered or subsidized more farmers may adopt the technology. Research needs to identify aspects of design that could reduce costs and enhance acceptance of technology. Further, just as cash crop farmers obtain government loans for crop development, a policy framework that makes it possible for households to access initial capital for biogas plants and pay later when they begin to benefit from the system is long overdue.

In terms of challenges faced in technology adoption, high installation costs and lack of credit facilities were reported by 70% of respondents as most limiting (Figure 5). Similar results were reported in a study in Tanzania by 95% of respondents (Mwakaje, 2008) and elsewhere by Quadir *et al*., (1995) and Mwirigi *et al*. (2014) who attributed high installation cost as key driver of the low adoption rates in many developing countries. In a study of the potential of biogas energy in Kenya, Jonušauskait (2010) found that costs were enhanced through imposition of duty of 25% and a 16% Value Added Tax of all imported biogas appliances, thus making the technology unattractive to most rural farmers. Social-cultural factors responsible for reduced

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adoption of biogas included among others marginalisation of women in decision making in biogas digester procurement and installation. The prevailing social structures on land tenure system vested in men decisions on all matters pertaining to the development and use of land. As such, women's efforts and willingness to own a biogas unit without the support from their husbands are constrained by their limited access and control of land, and thus difficulties in accessing credits, which was dependent on the same land as collateral.

In few cases, respondents viewed biogas technology as being dirty for cooking. However, a study by Mwakaje (2008) on bio-latrines showed that such negative attitudes disappear when the appropriateness and benefits of such technologies are physically demonstrated. Since "seeing is believing", there is need for on-farm training and demonstration of biogas technology. Absence of locally skilled biogas technicians forced farmers to seek experienced biogas installers outside their sub-county, thus adding to costs. In terms of operational challenges about 39% of the dairy farmers using plastic tubular digester faced low gas production especially during the wet and cold months of April-July (Figure 6).

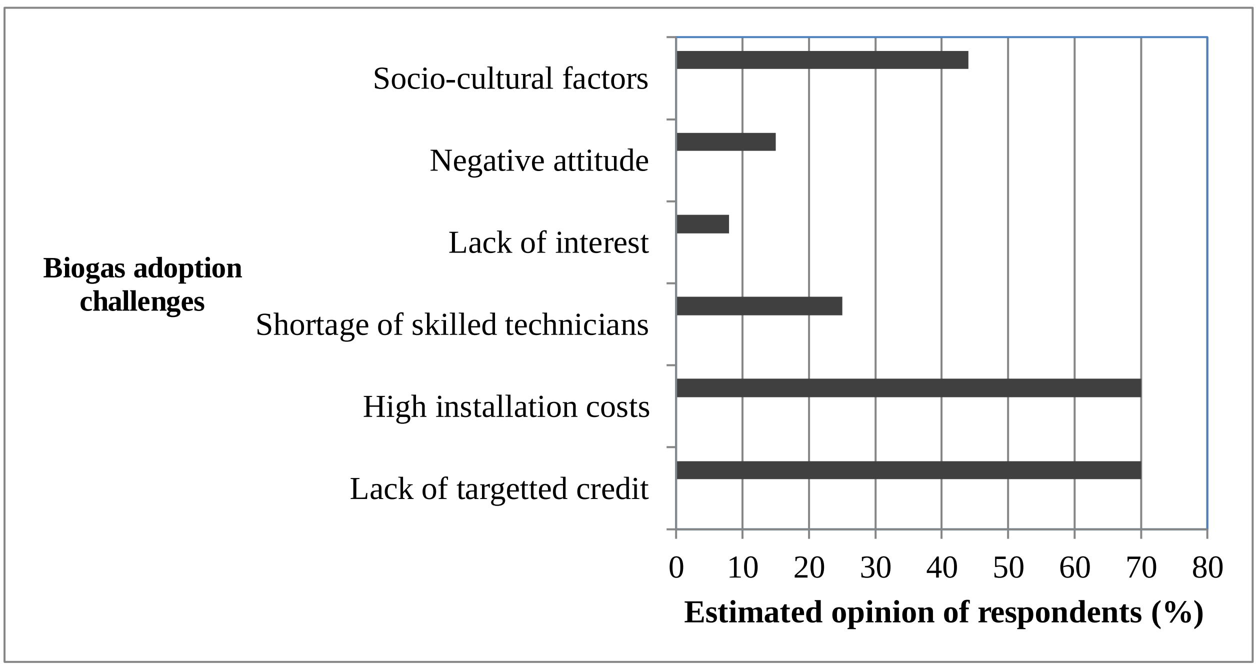

Figure 5: Challenges facing farmers in adopting biogas technology

Charcoal and firewood became obvious alternatives under such conditions. Vandalism and sabotage of plastic tubular sheet was another challenge. In most cases, the plastic tubular digesters are exposed to the sun to enhance anaerobic breakdown of organic materials. The risk of being damaged by external factors like sharp objects is real, but fencing around them has been used rather successfully. About 38.5 % of the biogas users reported gas leakages as one of the challenges of using biogas. It was common to see leaking pipes strapped with rubber insulators. About 16 % of the biogas users identified blockage of the inlet pipe as a problem they experienced once in a while. Although this calls for more competence in system monitoring, evaluation, and basic maintenance approaches among plant owners, having a positive attitude towards the technology would make farmers devote their energy and resources towards the success of the technology.

4.3 Challenges of Disseminating Biogas Technology in Mukurwe-ini

Key informant interviews indicated that the biogas extension agents in the study area were drawn from both private and public sector. The public actors were those from the core government ministries while the private biogas promoters were drawn mainly from self-help groups, private biogas technicians, local nongovernmental organization and individual farmers. The extension officers from the government provided extension services on biogas technology through the Home Economics Extension wing and sensitized the farmers about biogas under the auspices of the National Agriculture and Livestock Extension Programme (NALEP) during farmers' field days. The focus was on good management of livestock waste at the farm level. For both groups high costs of installation and inadequate operational funds were major limiting factors (Table 1).

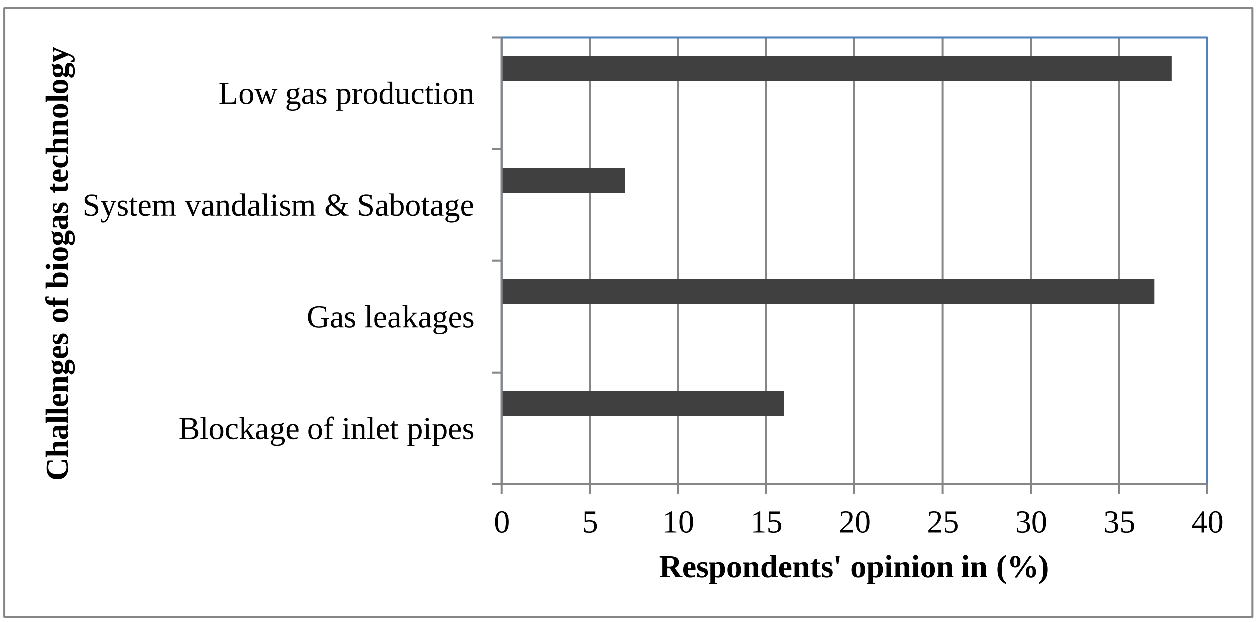

Figure 6: Respondents' opinions on challenges of using biogas technology (%)

Table 1: Opinion on constraints faced by public and private agents in biogas promotion

	Importance of constraint as estimated by respondents (%)	
Type of constraints	**Public Extension**	**Private Biogas Actors**
1. Lack of interest	8	-
2. Lack of credit	63	-
3. High installation costs	38	66
4. Lack of demonstration space	8	-
5. Poor promotion strategies	13	-
6. Inadequate funds	36	-
7. Few extension agents	18	-
8. Ignorance of biogas benefits	-	12
9. Shortage of locally trained installers	-	28
10. Gender issues	-	25
11. Limited Government support	-	18
12. Negative publicity	-	12

Inadequate credit facilities were a major constraint by public service providers due to the bureaucratic nature of government financial systems. The Kenyan government has in the past provided credit facilities to farmers to purchase inputs like seeds and fertilisers through the Agricultural Finance Corporation. A similar approach targeting biogas technology can be established. The private actors in the Mukurwe-ini promoted biogas technology by establishing demonstration farms, sourcing for funds from development partners and provision of subsidies and incentives to attract potential dairy farmers to install biogas plants in their farms. Sustaining this approach that seems to make dependence on external agencies would prove difficult in the long run. Understaffing prevented the public agents from providing individual attention to farmers often preferring to meet farmers in groups during farmers' field days.

Further no funds from government were specifically set aside to promote biogas. Instead it was treated as a cross-cutting issue with the consequence of not having a clear responsible government sector. In cases where funds were disbursed, bureaucratic delays still hampered their effective access and use. Lack of funds meant that biogas demonstration at the local level would be impossible. The only plant available was located about 30 kilometres in the county headquarters. This calls for institutional changes for popularizing biogas technology at the grass root level if more adoption is to be expected. This possibility is already envisaged in the national energy and petroleum policy whose overall objective is to ensure sustainable, adequate, affordable, competitive, secure and reliable supply of energy to meet national and county needs at least cost, while protecting and conserving the environment (Republic of Kenya, 2015)

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Gender issues were non-issues on the part of public extension services because the service collapsed and agents hardly visit farmers. Negative publicity of biogas technology as a result of poorly functioning biogas digesters was a major hurdle faced by the private biogas technology extension agents. According to the extension agents, some of the dairy farmers did not feed the digesters as advised by the technicians resulting to low gas production hence creating a negative image on the technology. In this regard, there is need for biogas technicians to train the dairy farmers on the frequency and adequacy of feeding the digesters in order to ensure that gas production is not affected.

Limited government support was also exemplified by its unfriendly tax regime. For instance, there was no imposed on electric generators whereas all imported biogas appliances were charged a duty of 25% and a VAT 16%. This calls for policy incentives to enforce rebates, waivers, and to promote local manufacture of biogas systems in order to enhance technology adoption. There is need for a forum to sensitise financial institutions to provide loans services on biogas procurement just like they provide loans services for purchase of LPG gas appliances, water tanks and other farm machinery.

5. CONCLUSION

The greatest opportunity of promoting biogas technology in Mukurwe-ini is the readily available raw material from the dairy zero-grazing units that most farmers have. The apparent low adoption of biogas technology is however mainly attributed to the high cost of digesters, high installation costs, low level of awareness about the technology, absence of locally trained technicians and poor institutional support from both the national and county governments. The promotional impact of both public and private biogas agents was constrained mainly by low institutional support from the government. The problem of low gas production and leakages was indicative of the need for quality designs and maintenance systems, hence the need for locally trained biogas technicians. To unlock the huge potential of biogas technology in Mukurwe-ini calls for among others:

- Establishment of a friendly biogas development credit fund for farmers to borrow money, invest and payback loans as they benefit from the technology.
- Both National and County governments should budget for biogas extension and promotion activities under the climate change mitigation programme framework.
- The need for County Energy and Agriculture Directorates to demonstrate at the farm level that biogas technology works and has superior social, economic and environmental benefits compared to reliance on wood fuel. This can significantly increase demand for the technology

- Arrangements to bulk raw materials from neighbouring farmers and invest in larger designs and appropriate gas distribution systems should be explored.
- There is need to develop a critical mass of local biogas technicians on the different biogas designs, their maintenance, repairs and quality control. The private sector and the civil society would come in handy and partner with the government in requisite training requirements.
- At the national level, education and training policy needs to deliberately embrace industrial ecology approaches and clean production mechanisms, when in particular it comes to agricultural waste management.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest with any agency or individual.

REFERENCES

Africa Biogas Partnership Programme (2016). http://www.snv.org/project/africa-biogas-partnership-programme-abpp/. Accessed on 15 December 2016

Biogas Digester for the Small Dairy Farmer (2016). http://www.nation.co.ke/business/seedsofgold/A-biogas-digester-for-the-small-dairy-farmer/2301238-2908512-734ti0/index.html. Accessed 15 December 2016.

Chirwa, P. W., Ham, C. and Maphiri, S. (2008). *A Report prepared for the Programme for Basic Energy and Conservation*. University of Stellenbosch, South Africa.

Choose the Type of Biogas System You Need (2016). http://theorganicfarmer.org/Articles/choose-type-biogas-system-you-need. Accessed on 15 December 2016.

Dahoo, C. (2011). *The Impacts of Bio-digesters on Kenyan Farm Women*. MSc. Thesis: Dalhousie University, Canada.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

FAO (2009). *Enabling Agriculture to Contribute to Climate Change Mitigation*, Rome

GTZ (2009). *Agro-industrial Biogas in Kenya. Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Herausgegeben von Ministry of Energy, Nairobi, Kenya

Hendrick, E.T., Bickman.L. and Rog, L.D. (1993). *Applied Research Design*. A Practical Guide, Sage Publications, New Delhi.

Jaetzold, R and Schmidt, H. (2007). *Farm Management Handbook of Kenya. Natural Conditions and Farm Information.* Vol.11B Central Kenya, Ministry of Agriculture, Nairobi, Kenya.

Jonušauskait, G. (2010). *Perceived Benefits and Challenges of Biogas Adoption among Households in Kenya.* IVM Institute for Environmental Studies, 1-59.

Karanja, G.M. and Kiruiro E.M. (2004). *Low-cost On-farm Biogas Production.* KARI Technical Publication Note No. 25, Nairobi.

Karanja, G.M. and Kiruiro, E.M. (2003) *Biogas Production.* KARI Technical Note No.10, Embu, Kenya

KENAFF (2014). *Kenya National Farmers Association Annual Report and Financial Statements*, Nairobi.

Kenya Agricultural Productivity and Agri-Business Project-KAPAP (2015). *Workshop on Agricultural waste management guidelines for smallholder farmers in Meru County*. 7-10th Sept 2015, Nkubu.

Kenya National Bureau of Statistics (2010). *The 2009 Kenya Population and Housing Census*, Republic of Kenya Vol. 1A.

Kenya Takes Lead in Biogas Use in Africa (2016). https://www.rwlwater.com/kenya-takes-lead-african-biogas-use/. Accessed on 15 December 2016.

Kibera Slum Seeks to Ground Flying Toilets (2015). http://www.dw.com/en/world-toilet-day-kibera-slum-seeks-to-ground-flying-toilets/. Accessed on 15 September 2015.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Lattimore B, Smith C.T, Titus B. D, Stupak, I and Egnell G. (2009). Environmental Factors in Woodfuel Production: Opportunities, Risks, and Criteria and Indicators for Sustainable Practices. *Biomass and Bioenergy*, 3 (3): 1321-1342.

Marchaim, U. (1992). *Biogas Processes for Sustainable Development*. FAO Agricultural Services Bulletin 95.

Masinde, S. and Karanja, L. (2011). *The Plunder of Kenya's Forests.* Global Corruption Report, 280-282

Muchiri, L. (2008). Gender and Equity in Bio Energy Access and Delivery in Kenya. Practical Action Eastern Africa.

Mukurwe-ini Constituency Strategic Plan. (2012). Mukurwe-ini Constituency Office, Nyeri, Kenya

Muradin, M and Zenon F Z (2014). Potential for Producing Biogas from Agricultural Waste in Rural Plants in Poland. *Sustainability. 6:* 5065-5074.

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

Mwirigi, J. W., P. M. Makenzia, et al., (2009). "Socio-economic Constraints to Adoption and Sustainability of Biogas Technology by Farmers in Nakuru Districts, Kenya" *Energy for Sustainable Development* 13 (2): 106-115.

Njagi K. (2016). Biogas Heats up in Kenya as Fuel of Choice for the Poor. http://news.trust.org/item/20160324121157-epqyi/. Accessed on 14 December 2016.

Quadir, S A, Mathur, S S. and Kandpal, T C. (1995). *Barriers to Dissemination of Renewable Energy*. Report of the Millennium Assessment WHO, Geneva.

Remedio E M. (2011). *Wood Energy and Livelihood Patterns*: A Case Study from the Philippines. Vol. 53.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Renewable Energy World. http://www.renewableenergyworld.com/news/2015/02/africas-first-grid-connected-biogas-plant-to-start-in-kenya.html. Accessed on 15th December 2015.

Republic of Kenya (2010). *National Constitution*. Government Printers, Nairobi.

Republic of Kenya (2015). *Draft National Energy and Petroleum Policy*. Ministry of Energy and Petroleum, Government Printers, Nairobi.

Republic of Kenya (2015). *Forest Policy*. Ministry of Environment, Water and Natural Resources. http://www.kenyaforestservice.org/documents/. Accessed on 9 September 2016.

Republic of Kenya, (2002). *Study on Kenya's Energy Supply and Policy Strategy for Households,* Final Report, Ministry of Energy, Nairobi, Kenya.

Rural Electrification Authority (2009). *Kenyan Electricity Expansion Project*. Resettlement Policy Framework 2.

Schwengels, P. (2009). *Dairy Manure Biogas Opportunities in Manica Province, Mozambique*. A Preliminary Assessment. Mozambique.

Shell Foundation (2007). *Biogas for Better Life*. An Africa Initiative, Nairobi, Kenya.

Speranza, C. I, Kiteme, B. and Opondo, M. (2009) *Adopting Public Agricultural Extension Services to Climate Change: Insight from Kenya.* German Development Institute

Sustainable Development Goals. https://sustainabledevelopment.un.org/topics. Accessed 15h December 2016.

Tafdrup, S. (1995). Viable Energy Production and Waste Recycling from Anaerobic Digestion of Manure and other Biomass Materials. *Biomass and Bio Energy*, 9 (1-5): 303-14.

Wakulima Dairy Limited. (2011). *Annual Report. Mukurwe-ini Sub-County*, Kenya.

World Vision-Kenya (2016). *Energy and Environment Partnership Evaluation Report for Wema and Mogotio Area Development Programmes*. Consultancy Report.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Zhu, T. (2012). Assessment of Small-scale Biogas Systems and their Widespread Dissemination in Cantho City, Vietnam. http://digitalcollections.sit.edu/isp_collection/303/. Accessed on 28 May 2016.

