Minireview Article

Biomass energy applications and development in Uganda

Abstract

This study investigates biomass energy applications and development in Uganda. Traditional biomass dominates Uganda's energy mix with 89% of overall primary energy consumption. Uganda must reduce traditional biomass energy consumption if it is to reinforce its sustainable development goals. It seeks to assess bioenergy applications; it also analyses drivers and barriers of biomass consumption.

The findings indicate an in-built use of traditional biomass because of the drivers that outweigh the constraints of its use. Suggested policy measures to transition to modern biomass energy consumption are made.

This study provides critical review of bioenergy application and development in the Ugandan setting. This is a landmark in informing the economic planner on the right policy direction of diversifying energy use.

Keywords: Biomass, Bioenergy, Bioelectricity, Uganda.

1. Introduction

1.1 Preamble

According to IEA (2019), due to increasing global energy consumption, global energy-related CO_2 emissions reached 33.1 Gt CO_2 in 2018, up by 1.7% relative to 2017 level, the greatest blame is on fossil fuels, the remedy is in either reducing fossil fuel consumption or reducing the overall carbon emissions. Biomass and bioenergy conversion technologies will meet the low atmospheric concentration of 350PPM atmospheric carbon dioxide (Azar et al., 2006, Luckow et al., 2010). Renewable energy consumption will avoid about 50% of carbon dioxide (CO2) emissions by 2050 (Barnejee 1999) heavy reliance on biomass can abate this if and only if modern biomass and bioenergy consumption is undertaken to promote sustainable growth and development.

The economic potential of harvesting biomass by coppicing wood combined with conversion technology in a biorefinery can constitute a formidable energy potential for Uganda. About 87% of Uganda's primary energy consumption is traditional biomass (NDP 2020), there are all reasons both economic and technical why Uganda may need to develop its biomass energy potential to sustainable use. Adopting the use of modern biomass reduces indoor air pollution and other related health and environmental hazards (Buyinza and Kapeller 2018, Mutumba et al.,

2021).With the right technology, it is possible for Uganda to extract its biomass potential to a sustainable extraction path.

Traditional biomass may mean the use of firewood, charcoal, crop wastes for cooking and lighting (Eleri and Eleri, 2009). This is an ineffective way of biomass energy application. It is important that innovations around this energy use fosters modern and more efficient use of biomass.
This paper seeks to establish biomass energy potential, drivers and barriers of biomass energy and suggest strategies to overcome them.

1.2 Bioenergy Resources and sustainable development

Globally, bioenergy accounts for 55% of renewable energy, it is a dominant energy source (Bildirici and Ersin, 2015). It constitutes 13% of primary energy consumption (Asumadu-Sarkodie et al., 2019), while 67% of all cooking is from biomass; it constitutes over 90% of rural energy consumption (IEA, 2019). The trend is reducing traditional biomass and rising modern biomass consumption (Gao & Zhang 2021). The sustainable development goal (SDG) 7 advocates for affordable and reliable clean energy for all by the year 2030. This then advocates for a quick transition from traditional to modern forms of biomass energy while taking into account the contribution biomass plays in avoiding carbon dioxide emissions.

Uganda is an energy starved country despite the abundance of energy resources. The access to electricity is limited due to low income per capita, so an average household can barely afford to purchase electricity to use; as such they heavily rely of fire wood, which in turn brings environmental hazards (Miito and Banadda 2017). This has often resulted into over deforestation, soil erosion and increased climate variability through reduced precipitation and longer drought periods. This has adverse effects on climatic variability and climatic change.

Bioenergy is a renewable energy source that is conveniently available. This explains why it is dominating in most of the Sub Saharan Africa. However, most of this is the traditional biomass, because of the insufficient technology to modernise its use.

In order to lead a sustainable livelihood, there is need to sensitise households in the value of transforming to the use of modern bioenergy. Rural households need to be supported into use of modern bioenergy. Creation of awareness as well as empowering these households to use energy sustainably is every ones role. This study is to provide a useful pattern for this transition from traditional to modern bioenergy use to occur. This will forge a way towards a sustainable livelihood framework.

1.3 Why this paper

Fundamental inadequacies in clean energy supplies has exacerbated energy poverty in Uganda, with an average Ugandan household spending 22% of their incomes on energy(Senono et al., 2021). Yet using traditional biomass for cooking is inherently dangerous leading to accidents and indoor air pollution (Fischer et al., 2011, Buyinza and Keppler 2018, Mutumba et al., 2021). It is

at this point that the use of modern biomass and bioenergy technologies is re-evaluated. An assessment of the drivers and challenges is carried out with a view of making strategic recommendations to inform policy basing on quality information.
The contribution of this paper therefore is to forge a safe transition from the traditional biomass to more modern bioenergy alternatives in the energy ladder. An in-depth analysis of the drivers and barriers of biomass energy have been explored.

1.4 The Roadmap for this paper

The rest of this paper is organised as status of bioenergy development in Uganda in section 2, theoretical framework in section 3, section 4 is materials and methods, results and discussion in section 5 and finally conclusions and further research.

2. Status of Bioenergy development in Uganda

About 89% of Uganda's primary energy consumption is traditional biomass (NDP 2020). Of this firewood constitutes 78.6%, charcoal 5.6% and crop residues 4.7%. Bioenergy can be harnessed from a variety of sources. They are used to generate power, their compatibility for a given conversion technology is what is important for this study. Biomass for energy generation comes from the following sources: Wood, including forest residue and shrubs, primary and secondary mill residues, wood cuttings, and briquettes, fast-growing crops grown specifically for energy use (fast-growing trees, grasses), energy crop waste, agricultural and animal residue, and food waste. Biomass is categorised as renewable energy since above a certain threshold, it has capacity to regenerate. Uganda's biomass energy potential is 1700MW, while peat and bog is estimated at 800MW giving a combined 2500MW, however, only 111.7MW (3.8% of bioenergy potential) biomass cogeneration has been developed. Uganda's energy consumption is 45.1 million tonnes of wood per year against a sustainable yield of 26 million tonnes (Miito and Banadda, 2017). The existing standing stock is 284.1 million tonnes.

Biomass is of critical importance to the Ugandan economy due to the following stylised facts

(i) It is renewable and self-replenishing, though not in infinite quantities, it is still abundant and gained the social acceptance. It reduces energy dependence issues with over 45 million tons of fuel wood consumed every year with some 19 million tons in excess of sustainable consumption rates. It is important to re-examine the use of biomass energy development alternatives.

(ii) It is convenient; obtainable from anywhere with relative ease; lowering energy security issues (Van Loo and Koppejan, 2008).

(iii) Helps reduce Balance of payment (BOP) deficits due to low energy imports, Uganda has made a maiden investment in modern energy and if it resorted to importing then BOP deficit would be too high (Payne, 2011). Uganda's energy trade balance deficit is kept small due to use of biomass energy consumption (BEC).

(iv) Contributing employment and improving livelihoods. Coppicing wood fuel and gathering biowaste is labor intensive (Hoekman, 2009).

(v) Bioenergy is convertible into solid, liquid, gas and these resources can be used in electricity cogeneration and heating (Demirbas, 2008). With appropriate bio refineries, it is the most diversified electricity source

(vi) Contribution to the environmental good by mitigating carbon dioxide emissions (CO2); (Bilgili, 2012). Bioelectricity is clean with a small amount of carbon dioxide emission. Emphasis should be on modernising biomass energy for better environmental quality.

(vii) Promoting energy security goals, a goal that Uganda is reluctant to pursue largely due to a complex energy system (Bilgili and Ozturk, 2015; Kumar et al., 2003, Mutumba et al., 2022).

Biomass can use a combined heat power (CHP) which is considered an up to date mature incomes of households increase. The likely switching to kerosene and LPG is strictly hindered not only by the costs of acquiring the technology to use these alternatives, but also the price volatility of these fuels. The socioeconomic status of most households makes biomass convenient and cheap. They also combustion technology coppiced wood (Poplar and straw) can be used as a fuel for gasification process. A biomass CHP plant is considered to have 9 MWe with an electricity conversion efficiency of 30% (Karaskota et al., 2013).

3.0 Theoretical framework

This study is guided by the energy stacking hypothesis (Kowsari and Zerriff 2011). According to this model households don't entirely abandon the traditional energy alternatives when their incomes increase. They adopt newer and modern alternatives while sticking to the traditional ones hence the stacking effect. The switching from one fuel source to another is not done perfectly which results into multiple fuel use. This therefore means it is not possible to entirely substitute the traditional biomass entirely (Masera et al., 2000).

The household that sticks to the using multiple energy sources along the energy ladder have been bound in social cultural attributes within the community in which they live. The existing stoves and the convenience of use. They are readily available for instance the three stone stove is flexible and could be mounted easily and cheaply in any space to allow cooking.

Significant economic progress is believed to diffuse energy stacking (Kang et al, 2019). This therefore means household incomes as well as energy prices will feed into the speed of transition. Where incomes grow and energy prices are constant transition can go on. While increasing household incomes and declining real energy prices cause energy transition and welfare gains. Biomass energy in Uganda is becoming tradable with distinct charcoal and even firewood markets. The fungibility of these commodities causes more energy stacking as the prices of these items are often increasing. The real incomes are static if not decreasing, this perpetuates energy stacking hence a stumbling block to energy transition.

The alternatives available to biomass include kerosene, Liquefied Petroleum Gas (LPG) and electricity as energy alternatives so as use technologies that are user friendly and simple.

Kerosene is itself not a sound replacement for biomass because of the inherent risk of its use and price volatility of this fossil fuel. This therefore leaves the poor households trapped in the energy poverty net. LPG is fairly unknown to many households, many are conservative to their socio cultural norms, they remain stuck to the use of three stone and charcoal stoves that they are accustomed to.

4.0 Materials and Methods

Qualitative research procedure were handy in gathering information for this paper (Merriam 2002, Mutumba et al., 2021a). It mainly concerned a review of relevant documents and empirical literature. The literature associated with biomass energy development with aspects of drivers and barriers of biomass energy.

Empirical literature was triangulated from varying sources of archival information (Kzillen & Jarrett 2007). Data from diverse digital sources such as journal articles, conference papers were compared with different sources (O'leary, Z. 2017).

This information was gathered in various themes. Information from documents were observed from a number of sources to establish their validity and attain a higher level of truths. Information profiled was then summarised and sequenced to derive greater meaning.

5.0 Results and discussion

5.1 Drivers of Bioenergy development in Uganda.

With the growing energy demand arising out of rapidly increasing population, there has been a need to find alternative sources of energy in Uganda which can meet this need yet at the same time clean, efficient, reliable and affordable. As such, bioenergy has been considered the best fit that could cover this unprecedented energy demand as well as soothing socio-economic activities in the country. Consequently, the following sub-section presents the main drivers for development of this renewable energy resource in Uganda for various applications in Uganda. The amount of energy that can be produced by a bio power system depends on several determinants, including the type of biomass, the energy conversion technology employed (technical factors) and economic factors. Bio power systems can be sized to supply internal energy needs only or sized larger to feed energy to the grid for sale.

5.1.1 The desire to meet the planned Uganda Vision 2040

This Vision is seeking to step up the country's overall electricity production from the 822 MW (in 2012) to 41 800 MW over the long term. Electricity consumption per capita which is currently 215kWh/year (2020) to increase to 3668 kWh/year in 2040 (GoU-V2040). The proposed distribution of installed capacity of power generation in Uganda in 2040 is shown in Table 1. As shown in this table, overall, renewable energy resources (hydropower, geothermal, bio energy and biomass) are expected to contribute 30.4% to national grid in 2040. Furthermore,

in can be deduced from the same table that, biomass and peat energy resource is expected to provide about 6% of the Uganda's installed power capacity by 2040 and 13.4% of renewable-based power capacity. However, the current installed capacity biomass energy-based power is 5.7% of 1700 MW target by 2040. To meet the government's target, therefore, there is great opportunity to investment and development bio energy resource by individual as well as private and public organizations in this country.

Table 1: Present and future cumulative power generation in Uganda.

Source of energy	Current installed capacity (MW), Jan 2022*	Proposed installed capacity (MW), 2040**
Hydropower	1 07.9	4 500
Geothermal energy	0	1 500
Solar	64.9	5 000
Biomass energy	111.7	1 700
Peat energy	0	800
Nuclear	0	24 000
Thermal	101.1	4 300
Total	1 350.6	41 800

*** ERA, 2022; **Uganda Vision 2040 document (pages 73-74)**

5.1.2. Energy Demand growth and access

Due to increasing population and economic activities, there has been a surge in electricity demand over time in Uganda in recent years. According to Ministry of Energy and mineral development strategic development plan 2019/20 – 2023/2024, electricity demand has been growing at an average of 10% per year. This growth in demand has led to occasional and unprecedented load shedding arising from unmatched supply which did not increase proportionately with the increase in demand. Furthermore, about 79.6% of the population is still left out in terms of access to electricity, and it was noted that, the household sector has the lowest levels of electricity access in Uganda (MEMD, 2019/20). As such, with this enormous increase in demand for electricity and supply-side opportunity, the development of bio energy in Uganda could serve supplementary role as source of energy for premises with access to grid electricity and major source of electricity for premises without electricity access. Otherwise, households and premises with unreliable supply and lack of electricity may tend to meet their growth in demand with the use of firewood and charcoal, which are unsustainable sources of energy as they pose a serious detriment to the environment.

5.1.3 Scaling down CO_2 Emission

It is noted that the energy sector accounts for over two-thirds of the total global greenhouse gas (GHG) emissions and about 80% contribution of carbon dioxide (CO_2) emissions (IEA, 2018). On this note, the energy sector should play a vital role in any efforts to scale down emissions and mitigate climate change, thereby achieving SDG 13. According to Relief Web (2019) it was observed that one of the main barriers facing Uganda and indeed limiting its ability to achieve the nationally determined contribution (NDC) is high greenhouse gas emissions emanating from unsustainable agricultural practices such as burning of the bushes, use of fertilizers and deforestation. Furthermore, other sectors contributing to GHG inventory include transportation,

industrial activities, domestic and commercial dependence on charcoal and firewood consumption. More so, the Second National Communication (SNC) in 2010 projected that by 2035, the transport sector would be the largest driver of growth in energy sector emissions, followed by residential, then manufacturing and finally construction (Grantham Research Institute on climate change, 2015).

Relatedly, the energy sector of Uganda is dominated by use of biomass inform of fuel wood, charcoal and agricultural residues, contributing 88% to national primary energy mix by mid-2019. (Draft National Energy Policy, 2019). Thus, the desire to safeguard the environment and control emissions in Uganda calls for the application and development of bio energy technologies as a renewable source. Bioenergy could be used in powering vehicles like the recently unveiled Kira Motors' electric buses known as Kayoola buses in Uganda. These buses would use bio energy instead of fossil fuels which are detrimental to the environment. In addition, in agro-processing industries such as tea processing industries, bio energy could be used for drying tea instead of using firewood. In nutshell, use of bio energy conversion systems would go a long way in mitigating against continuous increasing in GHG emissions in Uganda.

5.1.4 Establishment of the Energy Sector Reforms

In 2002, the Government of Uganda approved the National Energy Policy (Power sub-sector reform). This reform was aimed at stimulating provision of sufficient, consistent, and cost-effective power supply in Uganda to meet the increasing energy demand, as well as promote efficient operations of the power sector with the aim of driving energy access. Additionally, the reform provided opportunities for private organizations, businesses and individuals to invest and contribute electrical power generation in the country. As a result, Uganda has seen a number of private investors penetrate the bio energy market, such as G-tech Energy Solutions, Konserve Advisory Services Ltd, Bio Point Uganda, Kishen Enterprises (U) Ltd, Nughasa Power Solutions, JK-Energies Ltd, Makambo Technical Services Ltd, Power Trust Uganda Limited and UltraTec (U) Ltd. Additionally, the reform paved way for the initiation of the Renewable Energy Policy, which drive the application and development renewable energy resources (such as bio energy, geothermal and clean biomass energy products (biodiesel, biogas and cogeneration power plant (Kapika and Eberhard 2013). Therefore, as a result of the energy reform and favorable other related regulations, there are now more opportunities for different players (from individual, small-scale to large-scale enterprise in both private and public) to invest in bio energy development in this country.

5.1.5 Promote Access for Rural Electrification

Bio energy and the associated technologies have proved very successful in providing energy services to the remote and inaccessible areas of Uganda, such as on islands and mountainous areas, For instance, Kalangala District (Island) and the hills of Kigezi, Kabale, Kisoro, Mbale, Bududa and many other remote places where the national grid is likely not going to extend its services in the near future because of the associated costs of grid extension. Thus, applying bio energy technologies in these islands and mountains would serve as the most viable option in providing electricity to these locations. Moreover, some bio energy conversion systems are very portable available in different modular capacities and are easy to install. For examples, (1) bio

PV modules come in different sizes ranging from 5W to over 300 W; (2) bio heater technologies come in different sizes; (3) bio kits for charging the battery and for lighting appears in different sizes and contain number of plugging outlets. Therefore, individual and organizations can buy and install these systems, based on their energy need and economic ability.

Furthermore, it is possible combine bio energy technology with other energy resources to produce hybrid power plant such as bio PV-grid connected system and bio-diesel (thermal) power plant such as 1.6 MW Bio-Thermal hybrid power established at Bugala Island, in Kalangala District. This power plant is supplying electricity to over 40 out of 49 villages on this Island. Consequently, bio energy conversion system can be used as soothing factor for energy generation and supply in Uganda. A surge in bio energy development will thus be good source for expanding the energy mix and growing the share of domestic/household energy supply in the country, especially in rural communities

5.1.6 Improve livelihood through job opportunities and enhancement of economic impacts

The Uganda National Household Survey of 2016/17 carried by Uganda Bureau of Statistics (UBOS) found out that 13.3% of the Ugandan youths aged 18-30 years were unemployed. Furthermore, UBOS's population projections reports for 2015-2020 indicated that the youth age group constitutes 23% of the total national population. Therefore, this increased population coupled with increase rate unemployment among of the youth could be reduced through developing bio energy and promoting its use. Bio energy could be used to run clippers in barber shops, driers in saloons and other equipment. More so, the notable growth in markets for bio equipment such as the panels, chargers, batteries and so on and the wide spread of these technologies could lead to the creation of multitude of jobs in bio energy market supply chain, from the technical aspects (such as resource assessment, energy audit, design, installation, and maintenance) to business and market related jobs (such as bio energy promoters, sales and acquisition managers, sales supervisors, trainers for remote employees, call centre officers, credit officers and other relevant energy related job opportunities).

As a result, the youth would be in position to earn some income and improve on their livelihood as well as reduction in criminal activities among the youths. Therefore, promoting bio energy technologies in Uganda will play critical role in scaling down poverty levels as local communities will more likely benefit from employment opportunities, acquisition of various skills, investment prospects and transfer of technology. Subsequently, investing in bio energy application will help create enormous employment opportunities for the youth in Uganda. In a survey by UNEP (2014) on light and livelihoods it was noted *"lack of energy after dark can inhibit people's opportunities for earning income by cutting the productive day short due to insufficient or unreliable light".* Accordingly, bio energy could spur income generation as a result of increased time available for productive work. Job opportunities and potential of bio energy development have been observed in many countries. For instance, IRENA (2019) reported that bio PV and bio heating/cooling development provided 3.6 million and 0.8 million jobs globally, respectively in 2018.

5.1. 7. Feed-in-Tariffs

The high electricity prices due to grid extension costs have also paved way for the development and application of bio PV. In order to reinforce the development and application of bio energy sources, the Government of Uganda, like other countries, established Feed in Tariff (FiT) structure as a policy tool designed to stimulate investment in the renewable energy sources. FiT usually implies promising small-scale producers of energy such as bio an above-market price for what they deliver to the grid. In Uganda, the current FiT (Phase 4) is applicable to hydro power, bagasse and bio PV power projects, with installed capacity ranging from 0.5MW to 20 MW. For Bio PV, the initial FiT was fixed as US$ 0.11/kWh for projects, which are licensed between 2016 and 2018 (ERA-FiT-II, 2013).

Due to commercial maturity of this technology, the current FiT is now US$0.071/kWh for project licensed from 2019 to 2021 (ERA-FiT-IV, 2019). As shown in Table 1, the introduction of FiT has resulted in established of four bio PV power plants with total installed capacity of 50 MW and they are contracted for 20 years each on US$0.11/kWh. Unlike previous phases (I – III), where FiT covered all feasible renewable technologies in Uganda, it should be mentioned that in Phase 4, small hydro power plant up to 20MW and bagasse power generation are considered as priority renewable technologies in Uganda. This is reflected in lower FiT for bio PV when compared with these priority renewable technologies (as shown in Table 1).

5.2 Constraints to Bioenergy development in Uganda

Despite the drivers or benefits of bio energy development for individual, private and public in Uganda, as discussed in Section 3, there are a couple of issues that are limiting this development. Some of these issues or barriers are carefully presented in the following sub-sections.

5.2.1 Huge Initial Investment Cost

On average, over 10 million (or about 28% of the population) of Ugandans are living on less than US$1.90 per day (UNHS, 2017). On small-scale or rural households level, investing in the various bioenergy technologies components such as; biogas digester. This implies that there is generally low disposable income among the population yet investing in these technologies require substantial amounts.

5.2.2 Lack of information and public awareness

The slow development of modern biomass energy technologies in most parts of the developing world has been attributed to the lack of information and limited public awareness (Adebayo et al. 2018; Mustapa et al. 2010; Peidong et al. 2009). Additionally, Adebayo et al. (2018) highlighted that, some Ugandans have limited knowledge about bioenergy as well as the associated environmental and socio-economic benefits. Moreover, many Ugandans are aware of the convenience associated with the use of traditional biomass, yet limited awareness of modern bioenergy technologies which has constrained modern bioenergy energy prospects (Murphy et al. 2014). Additionally, Consumer education has been stressed as one of the top challenges facing the diffusion of bioenergy systems in rural areas in Kenya and the rest of Africa (Asamoah, 2013).

5.2.3 Lack of human capacity & training

Availability of trained professional to work and maintain bioenergy equipment is crucial for a successful disposition and development of bioenergy projects in Uganda. Furthermore, the development of modern bioenergy technologies calls for special skills in the areas engineering (bio systems, process and energy), physics and energy economics and governance, as well as business management and project planning and development (Wilkins, 2010). Nevertheless, capacity building in form of training on the use and development of such technologies is crucial for the enhancement of the varied skills of the different groups of people. As such, both users and non-users should be trained on how this resource could be tapped into and used. There is a lot of ignorance by the populace about the various uses of modern bioenergy. Ugandans require a platform where they can get technical and engineering training especially the artisans but also create an avenue for them to access spare parts which can be used in their training.

5.2.4 Inadequate Attention to Research and Development

Presently, there is limited research effort by the government of Uganda in the subject area. The government has done little in encouraging innovations in the area of developing bio energy technologies, and to be precise there is no any visible effort by the government to fund universities and other institutions of higher learning to conduct research on how to develop bio energy technologies (Painuly, 2001). Notably, there is no well noticeable bioenergy research and development program that is reinforced with government funding. Additionally, there are clear working systems that could foster quality international research and some collaborations that can speed up skills and technological transfer.

More so, the development of modern bioenergy technologies has been limited by the laxity on the government of Uganda to provide an enabling supportive environment. As a consequence, the local technical knowledge regarding these products is insufficient and, hence, associated technologies are imported expensively. Nonetheless, with a local skilled and semi- skilled workforce, Uganda could draw closer to the attainment of a sustainable Renewable Energy industry in the near future. This suggests that scholars from multidisciplinary backgrounds and research institutions are needed to champion the research and development activities in the country in the area of renewable energy and specifically bioenergy technologies.

5.2.5 The Effect of Covid-19 pandemic

Covid-19 is having an exclusively negative impact on the renewable sector. One of the main problems relates to the importation and distribution of equipment to power plants. Moreover, China, which is among the countries most heavily affected by the corona virus, is the main global producer of many clean energy technologies. Since corona virus has delayed deliveries from China, renewable energy companies are unable to comply with deadlines for equipment installation. For instance, in India alone 3,000 MW of bio and wind energy projects face delays, due to the corona lockdown. BYD Co Ltd (China), the world's leading producer of rechargeable batteries, was unable to complete tests of new models of rechargeable batteries due to the pandemic, and this has led to a reduction in the delivery volumes of rechargeable batteries for the European market and the rest of the world, Uganda inclusive (IRENA, 2020; Distribution system

operators' response, 2020). The importation of renewable energy technologies during COVID-19 period became difficult and the locals resorted to use of traditional biomass.

5.2.6 Socio cultural barrier

Most households use three stone fire and charcoal stoves for cooking. They have been accustomed to this for generations. There are behavioural attributes that these households are attached to and do not change easily. Therefore effort needs to be undertaken to cause a shift to modern and sustainable cooking options. The switching from traditional biomass to clean energy options must therefore be guided by clear and well guided policy decisions that are able to overcome the energy stacking effect.

5.3 Suggested Measures and Policy Recommendations

This section addresses the various policy interventions that may be adopted to help in overcoming the barriers identified and thus stimulate bioenergy application and development in Uganda. We now discuss the suggested potential policies and measures for bioenergy application in Uganda.

5.3.1 Energy Subsidy Transfer and Cost Reduction Measures

The government of Uganda may undertake an energy subsidy transfer to use of modern bioenergy technologies. More so undertaking this measure will go a long way in bridging the competitive gap that exists between renewable energy technologies such as bio energy technologies and fossil fuels (COMSATS; 2005). Moreover, instead of subsidizing kerosene, the government of Uganda should consider channelling its subsidies to bioenergy and bio electricity because they provide a cleaner and more efficient source of energy. Bioenergy technology is a clean source of energy provided to the end user at a lower cost.

5.3.2 Favorable Feed-in-Tariffs Policies (FiTs)

Decreasing FiT for bioenergy could discourage potential investors in Uganda. As such, according to FiT-phase 4, bioelectricity should be included in priority technologies for FiT. This withstanding, there is a need for this policy to be appropriately manned with the intent of inviting potential investors and at the same time their activities should be closely examined. Nonetheless, the government should appoint skilled personnel charged with the responsibility of handling the process of renewable energy feed-in-tariffs. Notably, satisfactory policies are prime requirements for the lasting sustainable bioenergy development. Consequently, ensuring that regulations are put in place and enforced is critical in building assurance to the prospective investors in bioenergy that the set regulations will remain stable, unambiguous and enforceable, thus stimulating future stability of the investments. Biomass cogeneration has a feed-in-tariff of US$ 0.0087, as such, the would-be investors may be induced to inject money into bioenergy sub sector. On the other hand, Renewable Energy FiTs in Uganda could serve as an invaluable policy means of growing bioenergy technology utilization, just like FiTs have been efficiently involved in numerous advanced, emerging and developing countries (DeMartino and Le Blanc, 2010).

5.3.3 Stimulation of ICT awareness

Information and communication technology (ICT) plays a fundamental role in rapid economic growth, productive capacity improvements, education, government and many others. Previously we noted that a need to create awareness and as well as capacity building. However, this may not be possible during this period of Covid 19 pandemic where most countries are in total lockdown. Capacity building can be achieved through the use of ICT. There is a need for the creation of online trainings on the use of bioenergy systems. This will go a stride in promoting numerous experiences in the areas of installation, operation and repairs of bio energy technology schemes and avail the information connected to bioenergy incentives and technologies and most importantly the policy framework for renewable Energy's as well as the application of these renewable energy equipment for modest investors in a timely manner. Additionally, the collection of such information from google, google scholar, Elsevier, Emerald insight and other sources could create an important window for learning more about the different biotechnologies thereby permitting workers to develop and become accustomed to bioenergy technologies for specific environmental settings.

5.3.4 Establishment of strong Quality Standards for Bio Energy Components.

There is a need for regularizing manufacturing processes in order to reinforce small and medium bioenergy industries in Uganda. Relatedly, there is urgency for the regulators such as Uganda National Bureau of Standards (UNBS) and other agencies of the government to come up with strict guidelines regarding the standard of bioenergy equipment that are imported and sold to citizens. UNBS should strictly administer suitable manufacturing standards and equipment specifications. The government of Uganda in the bid to strengthen enforcement of quality standards for bioenergy technologies developed renewable energy policy instruments, what remains unclear is how to create incentives that will induce local companies to assemble bio energy devices. Equally, to ensure sustainability of supply of these bio energy equipment, the government should encourage domestic manufacturers to be more innovative and start designing and producing these technologies in the country rather than continuing to import them. Additionally, the outbreak of Covid-19 pandemic should also act as stimulus to create more awareness for the government to begin encouraging local producers to become more innovative than relying on imports all the time.

6. Conclusions and further research

Over the years, Uganda has been hustling to disentangle its energy insufficiency problems. The country has been marred with increasing demand for energy resources but with a constraint on supply. This withstanding, Uganda is endowed with huge amounts of standing biomass stock in the country could meet all the citizens' energy needs if this resource alone is well developed. Nonetheless, the development of bioenergy systems in Uganda is affected by a number of obstacles such as; informational (in terms of knowledge and awareness), economic, institutional, social, and technical barriers. In an attempt to overcome these barriers, the government developed a multitude of policies. These policies were intended towards enriching renewable

energy technology deployment in the country. Nevertheless, a lot of policy challenges still prevail and so need timely redress. In another tone, these policies should work together in an integrated manner if the country is to attain the full potential of sustainable energy consistent with goal 7 of the United Nations Sustainable Development Goals.

Accordingly, this paper have attempts to provide a critical review of bioenergy application and development in the Ugandan setting. It points out the current bioenergy status in Uganda as well as the drivers, barriers and some policy interventions that could be utilized to scale down the challenges and barriers observed.

Finally, these policy interventions should be positioned on bridging the competitive gap between bioenergy application and fossil fuels through interventions such as establishing effective feed-in tariffs, energy subsidy transfers, and putting into consideration both the negative and positive excesses to externalities. Clearly, raising the enthusiasm of bioenergy is not sufficient enough; disagreements such as poor infrastructure, limited access to suitable funding and appropriate bio system technologies need to be addressed in order to attain full potential from its development. As such, once the main challenge of induced growth in bioenergy technology is done, then market diffusion will eventually follow suit. Consequently, the path towards the attainment of sustainable development goal (SDG7) of the United Nations, i.e. sustainable energy which is also affordable is not an easy thing to achieve yet at the same time there must be away out. The government should therefore devote all its effort on sustainability of bioenergy and the benefits that are likely to emerge from the use of these technologies on the triple bottom line, i.e. economic dimension, environmental, and social dimensions. All in all, investment in bioenergy technologies in Uganda today will go a long way in securing sustainable energy which is clean, affordable and efficient for the indefinite future.

For further study, more research needs to be undertaken on the slow adoption of modern biomass consumption despite a lower feed in tariff for biomass cogeneration and the possibility of selling this to the main grid. It is still unclear why household still rely on traditional biomass to such a big extent.

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