Opportunities and Barriers for the Development of Biogas Technologies in Kenya

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Abstract

The development of technologies for waste treatment, simultaneously with minimizing greenhouse gas emissions, has become a matter of great concern at global level. Biogas systems can help in the fight against global warming by avoiding to escape methane from organic waste, into the atmosphere. Biogas technology is of great benefit to the end users and the environment by energy, compost and nutrient recovery. Kenya is a country with a huge biomass potential. Implementing of biogas technology could be a proper solution for waste treatment and producing of electricity from renewable energy sources, as stipulated in the national constitution. This paper presents an overview on the current status of biogas technologies in Kenya and the main obstacles that have slowed down the development of this technology in the context of the major political and economic changes registered in Kenya industry. There are mentioned the main benefits which biogas plants could bring to the environment and also some common problems with biogas plants which have been noticed in Kenya.

Keywords: *Organic Waste, Anaerobic Digestion, Biogas Plants*

Introduction

In the last decades pollution of the air and water from municipal, industrial and agricultural operations has grown continuously. The emission of CO_2 and other greenhouse gases (GHG) has become an important concern at global level. Governments and industries are therefore increasingly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment while minimizing GHG.

Biogas is a combustible gas produced by the anaerobic digestion of organic material, e.g animal manure, human excreta, kitchen remains, straws and leaves through the action of micro-organisms. Biogas is primarily composed of methane (CH_4) and carbon dioxide (CO_2), with smaller amounts of carbon monoxide (CO), hydrogen sulfide (H_2S), ammonia (NH_3), nitrogen (N_2) and oxygen (O_2).

Biogas plants can successfully treat the organic fraction of wastes such as food and alcohol industry waste, crop waste, farm waste, municipal waste, sewage sludge etc. When used in a fully engineered system, biogas technology not only provides pollution prevention, but also allows for energy, compost and nutrient recovery. Thus a biogas plants can convert a disposal problem in to a profit centre. The biogas technology has three advantages over other technologies using renewable sources of energy for energy production. First, biogas is a relatively clean fuel with a high content of methane which can be used for the generation of electricity and/or heat energy. Second, fertilizer that could be applied on soils is obtained from the anaerobic digestion of waste (Taleghani & Kia, 2005; Kvasauskas & Baltrenas, 2009; Holm-Nielsen *et al*., 2009). Third, wastewaters can be purified and pathogen killed by passing it through the digesters at appropriate temperatures. In addition to the three advantanges, that is ecological, economical and agricultural, the development of biogas energy is distiquished by another no less important advantage, that is, social one. Social efficiency is achieved when additional jobs are created.

State of the Art in Biogas Technology in Kenya

Kenya is a tropical country and agriculture is the main stay of her economy. Kenya imports all its fuel oil and it cost the nation over 60% of the meager foreign currency earnings. Given such a situation which may continue for unforeseeable future, Kenya has formulated an energy policy which emphasize on renewable energy development (MoE, 2007). Among renewable energies in Kenya include, biomass, solar, wind, geothermal, hydro, biogas etc. Like many tropical countries, Kenya has plenty biomass resources that can be efficiently exploited in a manner that is both profitable and sustainable for energy such as biogas production. These biomasses include municipal solid wastes, agricultural, agro-industrial wastes, human excreta (Nyaanga *et al*., 2011; Kivaisi and Rubindamayugi, 1996; Sheya and Mushi, 2000; Mbuligwe & Kaseva, 2004; Chaggu *et al*., 2007). Also huge quantities of animal manure suitable for biogas production are generated from the animals each year.

Biogas technology utilizing animal waste is not new to Kenya; it was introduced in as early as the 1950s (Mbuthi & Muturi, 1999) by private stakeholders. In 1975, the government through the Small Industries Development Organisation introduced the Indian design in several institutions including secondary schools, rural health centres etc. The programme was supported by the German Agency for Technical Cooperation (GTZ). Under this programe the Chinnese fixed dome biogas digesters were adapted to local conditions (Sheya & Mushi, 2000). However, these technologies are based mostly on the use of animal manures as feedstocks for the biogas digesters. There is therefore a tendency to limit the technology to cattle manure rearing areas. Therefore, there is a great need for biogas research and development aimed at enhancement of biogas process using efficient cost effective high rate bioreactors and different biogas feedstock other than conventional used animal manures in traditional digesters currently used in Kenya. To this effect there is a scientific research going on the anaerobic digestion for biogas production for several years in Kenya. The biogas research and development has been centred mainly at Egerton University in collaboration with Kenya Agricultural Research Institute (KARI) and Ministry of Agriculture. Other institutions that have played an active role in the promotion of biogas technology include: Special Energy Program (SEP), a joint effort between GTZ, Ministry of Energy, Ministry of Livestock Development and Kenya Industrial Estates (KIE); Kenya woodfuel and Agroforestry Project (KWAP); Christian Intermediate Technology Center (CITC); Tunnel Technology Ltd; Biogas Africa and Kentainers.

Digested material from an established reactor or similar materials such as ruminant manure is often used to seed a new bioreactor, reducing the start-up time. Many bioreactors use methods of inoculating the fresh material with either digested material or the liquid fraction from the bioreactor, thus reducing washout of microbes. The microbial populations available in rumen fluid have been used as a seeding material in anaerobic digestion lignocellulosic feedstocks often to increase the production of fatty acids, which subsequently enhance biogas production. The potential application of rumen microorganisms to anaerobic digestion of agricultural, agro-industrial, water hyacinth rich lignocellulosic material singly or combination was found to improve biogas production elsewhere (Kivaisi *et al*., 1990, 1992; Kivaisi & Eliapenda, 1995; Kivaisi & Mtila, 2001). However, in Kenya the source of innoculum and substrate/feedstocks is the cow-dung which as hampered the development of the biogas technology in the country.

Pre-treatment of feedstocks can increase biogas production and volatile solids reduction due to increased solubilisation. The use of pre-treatments is particularly useful in the digestion of biomass feedstocks, as these tend to be high in cellulose or lignin. Pre-treatments can break down these recalcitrant polymers physically, chemically or biologically. These have been shown to be effective in anaerobic digestion of lignocellulosic wastes such as baggasse, maize bran, water hyacinth, sisal leaf decortications residues leading to significant increase in methane yield compared to the untreated (Kivaisi & Eliapenda, 1994, 1995; Katima, 2001; Mshandete *et al*., 2005, 2006). Additives enhances the production rate of a bioreactor or increase the speed of start up, which ultimately improve biogas plant performance significantly. Soyabean curd residue O*kara* as an additive has been reported elsewhere to enhance methane production from pretreated woody waste (Take *et al*., 2005). However, pre-treatment of the feedstocks before anaerobic digestion has not been done yet in Kenya which reduces the solubilization of the feedstock residues.

Co-digestion of organic wastes is a technology that is increasingly being applied for simultaneous treatment of several solid and liquid organic wastes. The main advantages of this technology are improved methane yield because of the supply of additional nutrients from the co-digestates and more efficient use of equipment and cost sharing by processing multiple waste streams in a single facility. Co-digestion of organic fractions of municipal solids waste, sisal leaf decortications residues, coffee hulls with chicken manure or fish waste or cow dung manure improved the digestability of the materials resulting in increased methane productivity and methane yield (Kivaisi, 2002; Kivaisi & Mukisa, 200; Mshandete *et al*., 2004). However, in Kenya, there is no co-digestion of waste materials in the digesters and where it exists, the mixture is made of two substrates, cow dung being the major component of the mixture.

Reasons to Implement a Biogas Technology

Biogas is a carbon neutral way of energy supply. The substrate from the plants and animals only emit the carbon dioxide they have accumulated during their life cycle and which they would have emitted also without the energetic utilization. On the whole, electricity produced from biogas produces much less carbon dioxide than conventional energy supply. 1 kW of electricity produced by biogas plants prevents 7,000 kg CO_2 per year. Biogas burns with a hot blue flame and can be used for cooking, lighting and to run refrigerators.

Biogas can be used for all applications designed for natural gas. It can be used as a fuel in power generators, engines, boilers and burners. While producing electricity, heat energy can also be recovered by using a co-generator which usually contains an internal combustion engine or power turbine and heat exchanger to capture the heat generated while electricity is produced. Thus co-generators have higher efficiency in energy production when compared to other electricity generators (Butchaiah, 2006).

The sludge resulted after digestion is rich in basic nutrients such as high quality fertilizer, so there is no waste in biogas technologies (Bhat *et al*., 2001). Apart from getting biogas and fertilizer, decomposition and fermentation of organic material in biogas digesters improves sanitation because the gas and the slurry/sludge obtained does not usually smell, and moreover breeding site for flies and mosquitoes, which transmit disease are eliminated. Most of the pathogens are also killed during the fermentation process.

There are many benefits resulting from the use of biogas technology, as following:

1. *Waste treatments benefits*: It is a natural waste treatment process, requiring less land than aerobic composting. The treatment process also reduces disposed waste volume and mass.
2. *Energy benefits*: It is a net energy producing process and normally generates high quality renewable fuel.
3. *Environmental benefits*: It significally reduces greenhouse gas and eliminates noxious odors from the environment. More so it produces a sanitized compost and nutrient-rich liguid fertilizer with biopesticide effects.
4. *Health related benefits*: The technology improves the sanitations through reduction of pathogens, worm eggs and flies.
5. *Economic benefits*: Considering the whole life-cycle, it is more emissions cost-effective than other treatment options. Jobs can also be created related to the design, operation and manufacture of energy recovery systems.

In spite of these strong environmental and economic benefits, the production and use of biogas is not yet a common application in Kenya due to the main market barriers: lack of knowledge and experience of farmers, biogas plant operators and engineering companies, lack of awareness of decision makers, and insufficient access to funding sources (www.big-east.eu).

Potential Barriers in Development of Biogas Plants

Biogas technology in Kenya dates back to the mid 1950s (Mbuthi & Muturi, 1999). The rate of adoption has been slow and affected by:

1. Prohibitively high cost of installations
2. Inadequate labor for biogas plant operation and maintenance
3. Lack of adequate operational information to optimize biogas plant performance
4. Technical problems resulting in gas leakages and comparatively low gas yields (Karanja & Kiruiro, 2003; Mbuthi & Muturi, 1999).

History shows that biogas plants have always been introduced with success in other countries. However, in many years, the focus of the government policies was on biogas quantity not quality. This resulted in badly functioning digesters, many of them being not in operation today.

The situation is similar also in Kenya. Many biogas plants that were treating farm waste and sludge from municipal wastewater treatment facilities are not operational now due to difficulty of financing and poor maintenance.

To develop and implement biogas technology at large scale it would be useful for Kenya to benefit from the experience of the developed countries in this field and to avoid the obstacles these countries faced during their growth.

Biogas systems require a financial investment which is an important obstacle in biogas plants development in Kenya and also a management responsibility. The main financial obligations associated with building an anaerobic digester include capital (equipment and construction and associated site work), project development (technical, legal and planning consultants; financing; utilities connection and training costs as reported elsewhere (Koopmans, 1998).

Installing and operating costs for biogas plants vary significantly as a function of their capacities. For example, in Germany a small biogas plant (100-500kW), owned by a few farmers working together, cost about 1.5 million Euro. The government doesn't supply any funding for the construction of the plants, but because the revenue that these plants earn is guaranteed for 20 years, it is easy to get loans at a low interest rate from commercial banks. A large capacity biogas plant which generates an electrical output of 4 MW needs an investment up to 15million Euro. In USA, for a biogas plant with loading rate of 82-110m^3/day organic waste and a biogas production of 850-1150m^3/day, the investment costs reach 290000-600000 USD. In Kenya, there no such loans benefits to the farmers and thus no joint biogas plants that have been established. However, it is advisable that Kenya government to embrass what other developed countries are doing to promote the biogas technology. Nonetheless, the major constraints to biogas technology dissemination include: High initial investment costs compounded with lacking credit schemes; Negative image caused by failed biogas plants and limited private sector involvement.

According to the experience of biogas plant, development in the last 63 years, it can be said that biogas technologies development in Kenya depends on the donor for funding renewable energies. Each country has got its own development rate and this means that it is not possible to develop these energies without political and governmental support (Fischer & Krieg, 2005).

In making a decision to install a biogas plant, one must realize that the system will require continuous monitoring and routine maintenance and repair that should not be underestimated. In Kenya majority of digester failures over the last years were the results of management and biochemical problems. All the problems of a biogas plant can be minimized or removed completely with a good design and proper operation and management.

Biogas plant projects have significant capital and operating costs and therefore, may not be financially viable for any application. The biogas experience of some developed countries having great practice in biogas technology (Denmark, Germany, Austria among others) has demonstrated that biogas technology is not applicable for all farms and all climates, since anaerobic digestion is a biochemical process that occurs properly at temperatures around 35-37° C. Low temperatures during the nights and the added capital investment are significant obstacle for successful implementation of biogas plants. However, this challenge can be ameliorated by developing effective microorganisms that can survive in a wide range of temperatures. In many situations, it can be a cost-effective and environmentally friendly method for treating manure and liquid waste. Biogas production in Kenya is best suited for farms that handle large amounts of manure as a liquid, slurry, or semi-solid with little or no bedding added (Widodo & dan Elita, 2005).

In addition, operating a biogas plant involves complying with some very vital specific safety requirements. The digester should be located away from farm buildings. Methane can cause explosions even at concentrations as low as 5 percent to 15 percent in air. It is desirable to install a gas detector (to monitor either the level of oxygen or methane in the room or space) and alarm devices in buildings with potential explosion hazards. Apart from being explosive, methane can displace the oxygen in a confined space and results in injuries or even death due to asphyxiation.

The biogas plants must be designed by experienced digester designers, who are well versed with the common problems associated with these types of systems.

Conclusion

The energy from the biogas is a renewable energy and reduces greenhouse gas emissions (carbon dioxide, methane and nitrous oxide).

The technology is popular for treating biodegradable waste as valuable fuel and ecological fertilizer can be produced along with destroying disease-causing pathogens and reducing the volume of disposed waste. The production of biogas is sustainable, renewable, carbon neutral and reduces the dependency from imported fossil fuels.

In Kenya, biogas has been used in the past to a larger amount. Due to socio-economical and political aspects, the biogas production has slowed down significantly compared with the current population. The development of biogas plants was limited by weak domestic financial resources for investment and lack of governmental financial support. Nowadays, there are operational only few biogas plants within wastewater treatment plants.

The development and implementation of biogas technologies could bring many environmental, energetically and economical benefits, solving important problems such as waste disposal and renewable energy supply.

Kenya has a significant potential in organic waste, including waste generated in forestry sector, agro-food industry, municipal biodegradable wastes and effluents from wastewater treatment facilities. This fact provides a good opportunity to develop anaerobic digestion technologies in Kenya.

The energy policy focused on efficient and economical energy supply must be changed with a policy towards clean and environmental energy resources.

Recommendations

While there is ongoing research worldwide in the first and second generation of bioenergy technologies, it is important to actively involve and fully engage Kenyan researchers and academic communities. This would entail joint research programs between developed and developing counties of Kenya with possibility for technological transfer to low technology counties. In order for biogas technology research to have a positive impact, the relevant and appropriate areas of research need to be identified and prioritized. Prioritization of biogas technology research activities results in the selection of the optimal research portfolio given the resource constraints. Thus, resource allocations based on the identified research priorities will be more efficient and responsive to the research system objectives than when resource allocation is not based on research priorities.

Most counties of Kenya are endowed with abundant biomass resources which include agricultural, municipal, industrial and sewage wastewater for anaerobic digestion and therefore, biogas production. These resources consist of a wide range of forms, classes and fractions. Researchers need to focus on the resources sustainably available locally and carry out investigations that would result in optimized biogas production from them following the stages of anaerobic digestion. Co-digestion of the substrate can provide opportunities to optimize biogas production in Kenya.

In order to promote the implementation and proper use of anaerobic digestion technology, it is important to initiate long-term anaerobic digestion and other renewable energy training and capacity building programmes, and to perform scientific work in this field (through appropriate research). It is important to establish contacts between research and University groups and experienced contractors, and to initiate collaboration with polluting industries, that is, to interest them in the system, either for use as an environmental protection method, or for energy production. Stakeholders and partners including farmers' extension agents, academics, processors, NGOs, donors, business and policy makers must be involved in setting research and development priorities. Involvement is essential to ensure that research is relevant to the needs of the targets and adequate research funding is guaranteed. In addition, experts should provide reliable and pertinent information about the biogas technology and its potential authorities, politicians, and public in general. It demands a lot of efforts in achieving an efficient transfer of knowledge.

In developing counties of Kenya, biogas energy research should be planned and conducted as the main factor leading to its contribution to the solution of energy problems at the local settings. Keeping this in mind, the results of the research should be applicable on a nationwide scale and constitute a part of the country's development plan. In many of the developing counties, there remain some basic research areas mostly on the quality and potential biogas yield of fermentable organic wastes available, the size and type of biogas digesters which can be economically viable for the potential consumers of the biogas technology, and characterization of the micro-biome of the Kenyan digesters.

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