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Dissemination and Problems of African Biogas Technology

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ABSTRACT

The present status of biogas technology in Africa was briefly reviewed focusing on biogas market potential, stakeholders, investments and bottlenecks. Africa is endowed with important biomass reserve considered as a potential for anaerobic digestion. However, the over reliance on wood and fossil fuels remains significantly overwhelming. This is due to the number of challenges in the field which led to underestimate at some extent the benefits of biogas technology. Unreliable and inefficient use of biomass fuel, which contributes to the greenhouse gas emissions still, has kept its preference in primary energy balance. Despite the huge potentialities and biomass resources for anaerobic digestion in Africa, the dissemination rate of biogas in Africa is struggling to meet biogas market demand. Nevertheless, there are a number of problems to address especially narrowing down the gap between biogas market demand and supply. This paper consists of an introduction and the status of the energy sector in Africa, and then discusses current dissemination of biogas development, finance and stakeholder contributions, challenges and a conclusion.

Keywords: African Biogas; Dissemination; Potential; Bottlenecks; Benefits

1. Introduction

Biogas technology belongs to Biomass energy which refers to a wide range of biomass fuels such as wood, charcoal, agricultural residues and animal waste. Biomass fuels are often used in its traditional and unprocessed form. African countries continue to mostly rely on biomass to meet the bulk of their household energy requirements. The wood fuel scarcity issue has been intensified by overpopulation, need for cropland, deforestation and high wood fuels demand usually in the form of charcoal, accelerating the problem.

Africa faces the problem of low energy consumption especially in rural area. Only South Africa consumes 45% of the total electricity generated in Africa while North Africa consumes 30%, and this effectively leaves Sub Saharan Africa where 80% of the continent population lives with only 24% of the total electricity generated in Africa [1].

Biomass energy conversion would assist in mitigating the negative impact of wood fuels and high fossil fuel imports, by producing biogas as alternative energy [2]. It may also create opportunity towards unemployment reduction, livestock industry development; and hence, rural people's welfare may be improved. Biogas technology benefits are not only limited to energy for cooking, lighting, power generation or biofuel. There are other benefits like bio-effluent as fertilizer which farmers need and used to buy. Its positive effect on the soil quality, benefits associated with animal husbandry and green-house gas emission reductions should not be sidelined.

Biomass energy resources in Africa are not yet fully exploited, mainly due to the limited biomass energy policy and low investment level. Biogas technology has been introduced four decades ago with a phase marked by pilot projects and training of technicians [3]. However, low access level, lower utilization capacity and maintenance deficiency are usually the characteristics of biogas technology in Africa.

1.1. Review on Household Biogas Designs

There is a good startup in developing household digester where contribution from various scientists, engineers and academicians found to be an important endorsement. It is characterized by different design forms; rectangle, spherical, ground and underground digesters. Similarly, the construction materials vary from mild steel to plastic sheet and masonry works.

The biogas plants today are multi-functional depending upon their purposes such as sanitation, energy recovery, wastes management and environmental protection.

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Their concept basically responds to its specific purposes, size and anaerobic digestion model. The concept design and different design options have impact on gas production rate, investment cost, digester monitoring and environmental conditions. The effective application of these concepts ensures whether the digester will perform well. The fixed dome design models are playing a major role in the dissemination of household biogas technology in Africa despite an increasing number of designs on the market, from which the popular ones are as follows.

1.2. Fixed Dome Chinese Digester

It has been experimented in China as early as the mid 1970's and standardized in 2002 as Chinese GB/T4750-2002, the profile **Figure 1**. This model consists of an underground brick masonry and cement mortar compartment for the digestion chamber with a concrete dome on the top for gas storage. Thus, in this design the digestion chamber and the gas storage dome are combined as one unit. This design eliminates the use of costlier mild steel gasholder and presents other benefits over Floating drum digester.

Based on the fixed dome Chinese model principle, various countries have put forth modified design to suit out local conditions. The GGC 2047 design model was adapted in Nepal with some similarities to Chinese fixed dome model, the profile **Figure 2**, and in both designs the size corresponds to the actual volume. The GGC 2047 model is also SNV main promotion methane tank type. It is now gaining the popularity due to the fact that it is said to reduce gas leakage often occurring at the gas pipe sealing place.

The Center for Agricultural Mechanization and Rural Technology (CAMARTEC) biogas design model has come in the same perspective with GGC 2047 model in Tanzania. It is widely used in East African region known as CARMATEC design model, the profile **Figure 3** [4]. It consists of an underground brick masonry compartment, fermentation chamber, with a dome on the top for gas storage. In this design, the fermentation chamber and gas holder are totally combined as one unit. Besides, there is no scientific recommendation about those design models so that the potential client may know which design model suitable for each specific case.

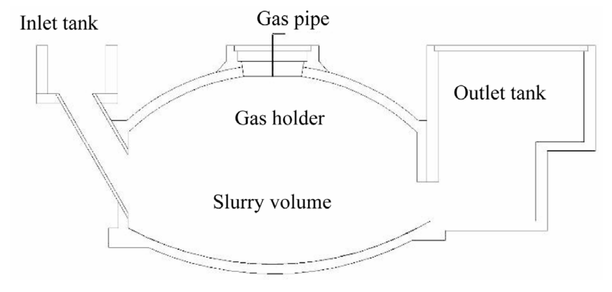

Figure 1. Chinese fixed dome model.

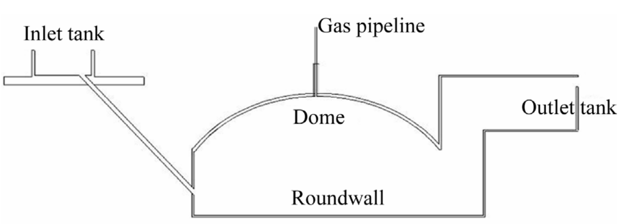

Figure 2. GGC 2047 fixed dome model.

1.3. Floating Drum Digester

Indian design model which began in the late 1930 and in 1962 the model gained the popularity in India as well as the sub-continent [5]. In the Khadi and Village Industries Commission (KVIC) design, the digester chamber is made of brick masonry in cement mortar, the profile **Figure 4**. A mild steel drum is placed on top of the digester chamber to store the gas produced.

Thus, there are two separate structures for gas production and gas collection. When biogas gas is produced, the gas pressure pushes the mild steel drum upwards and as the gas is being used the drum gradually lowers down. Thus, by observing the level of drum, one can assess the available gas volume as long as the mild steel drum floats above the digestion chamber. With the introduction of the fixed dome Chinese model biogas digester, the floating drum biogas plant model has become obsolete due to comparatively high investment, maintenance cost

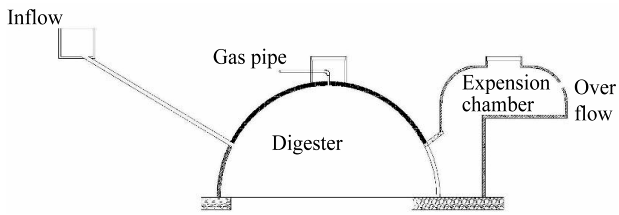

Figure 3. CARMATEC fixed dome model.

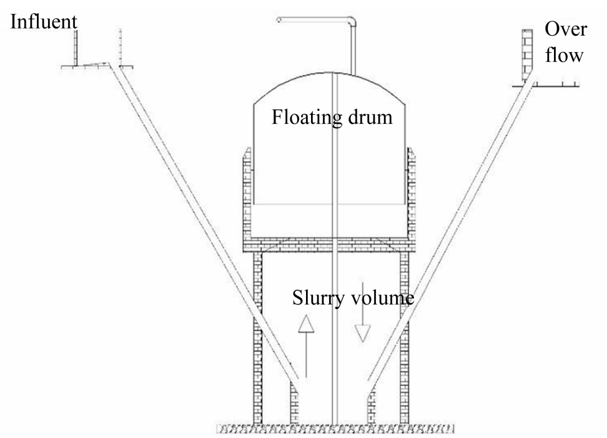

Figure 4. KVIC biogas plant model.

and some design weaknesses.

2. Current Dissemination Status and Market Potentiality in Africa

Domestic biogas was introduced in some Africa countries in around four decades ago. However, remarkable involvement came later in 2008. A number of NGOs joined in the promotion of the technology and accelerated awareness and dissemination. The result from biogas initiatives and national programs showed that there is a significant increase in number of installed biogas digesters and possible technical skills, considered as promising upshot for biogas technology in Africa, have been put in place. This increase is seen in nine countries supported by SNV where at least 17,000 digesters have been so far installed in five years, from 2007 to June 2012, profile **Figure 5** [6].

This was a good uptake, but still the dissemination rate is below its expectation and seems to be not convincing considering biogas market potential and targets in some selected countries as shown, in profile **Figure 6**, and overall target of the year 2020.

The potential for biogas dissemination in Africa may be defined by biomass resources available for anaerobic digestion, its affordability and climate versatility. This potential is a projection of the data available on number of livestock, agricultural residues, forest residues and municipal wastes [8]. This scenario shows that biogas market in Africa is still potential but making use of these potentialities is not materialized.

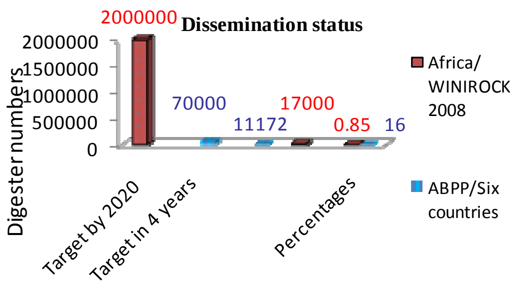

Figure 5. Target and achievement comparison in Africa.

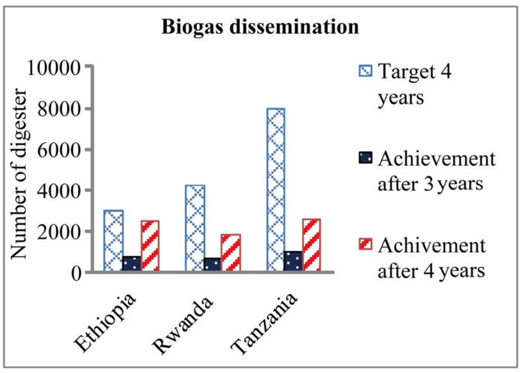

Figure 6. Target and achievement comparison in selected countries country. Source: Biogas for better life and Africa biogas partnership program [7].

According to the report of biogas for a better life 2007, the technical potential carried out has found that, for the continent as a whole, 24% of agricultural households would qualify for biogas hence they meet the two basic requirements, sufficient availability of feeding material and water to run biodigester. Reminding that, the total cattle population of Africa amounts to 277 million heads a FAO-2006 figure, with an estimated 168 million domestic cattle heads [9]. Taking some assumptions into account the technical potential market for domestic biogas in Africa would be estimated at 18.5 million households [10].

Furthermore, the biogas would be seen as a quick mitigation on pressure associated with low level of rural electrification, available power generation and a low financial investment in this field. Moreover, the depletion of biomass fuels and soil quality, increase of agricultural residues, municipal waste threats, pressing need of safe environment and sustainable sanitation all justify the need to go for biogas technology.

2.1. Biogas Market Potential in Intertropical Zone

Lying within tropics equally to north and south of equator, biomass resources in this zone are unevenly redistributed. They are gradually concentrated in zone extending from The Democratic Republic of Congo, the long of the coastal zone of South West of Africa up to Senegal [11]. It covers also Central, East and South East of Africa. It is the region with high opportunities with all suitable conditions and requirements for installation of biogas digesters. Around 70% of African population lives in the region.

2.2. Biogas Market Potential in North and South African Zone

The North Africa is dominated with Sahara desert from East to West of Africa and the Sahel, the zone between desert and Sub Saharan Africa. This part of Africa faces the water scarcity problems and is known for its cattle grazing and migrant population. It is obvious that most households in this zone may not meet basic requirement for installation of biogas digesters

Kalahari semi-arid sandy savannah located South-West of Africa supports more animals and plants than a true desert. Biogas technology can be adapted at a certain level in this region. Nonetheless, some countries like Morocco, Tunisia and Botswana, despite their major part in desert, have been committed to install some biogas units. The potential for biogas, for example, in one region Souss-Massa of Morocco was defined to have, according to biomass available, approximately 20,000 potential biogas plants [12].

2.3. Biogas Dissemination across Africa

To comply with safe environmental and sanitary conditions, large, medium and household biogas digesters have been installed in several African countries. It includes countries like Burundi, Botswana, Burkina Faso, Cote d'Ivoire, Ethiopia, Ghana, Guinea, Lesotho, Namibia, Nigeria, Rwanda, Zimbabwe, Tunisia, Morocco, Tanzania, South Africa and Uganda. Those biogas digesters utilize a variety of feedstock such as waste from slaughterhouses, industrial waste, animal dung and human excreta. Some few examples are: biogas digesters to treat chicken manure and dairy farm manure in Burundi, public latrines block in Kenya, prisons and boarding schools in Rwanda, health clinics and Sisal waste in Tanzania [13].

However, as far as biogas and anaerobic technology are concerned, South Africa is unique in Sub-Saharan Africa with advanced anaerobic digestion because of its high level of economic development and many universities with state of the art research capacities. Thus, household digester is the most attempted model and is often fed with domestic animal manure in Africa. This is due to the fact that this technology is closely linked to poverty alleviation and rural development [14].

3. Initiatives and Investment from International Organizations

Since 2008, several stakeholders have been engaged in different Initiatives and Partnership programs supporting development of biogas technology in Africa [15]. It comprises mainly Netherlands Development Organization (SNV), Netherland Directorate General for International Cooperation (DGIS), German Technical Cooperation (GIZ), WINROCK International, International Humanist Institute for Cooperation with Developing Countries (HIVOS) and Biogas Institute of Ministry of Agriculture, China (BIOMA) which provides technical support for domestic biogas programs. Their main objective is to develop marketable biogas technology by providing access to a reliable and sustainable clean energy in Africa.

The African Biogas Partnership Program (ABPP) is a famous partnership working with Netherland Directorate General for International Cooperation (DGIS) and SNV provides technical advisor. ABPP aims to support the establishment of commercially viable domestic biogas sector in six selected countries in Africa (Senegal, Burkina Faso, Ethiopia, Tanzania, Uganda and Kenya). This program began in 2008, in cooperation with HIVOS, with an aim to reach 70,000 households by 2013 and optimize organizational and institutional capacities already available in its working zone. In addition, Cameroon is developing its program since 2009 and Benin since 2010 [16].

Africa biogas initiative was launched in a conference held in Nairobi-Kenya in 2005 and attended by 135 delegates from 27 African countries, an initiative for installation of 2 million biogas units by 2020 supported by WINROCK [17]. Another technical major support in African biogas technology is provided by Chinese government throughout Biogas Institute of Ministry of agriculture (BIOMA) to the technicians and policy implementers from governmental institutions since 1984. BIOMA has installed biogas digesters in different countries in Africa and 55 international training courses and seminars in biogas or renewable energy technology have been held in BIOMA, Chengdu-China. At least 1300 international biogas experts and technicians from 123 countries have been trained in BIOMA and around 60% of participants were coming from Africa. This support from different stakeholders underlines the importance of biogas technology in Africa, but there is no appropriate coordination of these partnerships in order to avoid duplication or overlapping activities.

The financial conditions and purchasing power for some households in Africa seems to impede the widespread of biogas technology in most of African countries. Due to this, some stakeholders raise up the idea of subsidy to support and speed up the dissemination. Some countries in Africa are said to have adopted subsidy scheme, Rwanda, Ethiopia, and Tanzania among others, provide subsidies throughout national biogas programs. The reluctance in providing subsidy seems to be a drawback for successful large scale dissemination of the biogas technology, hence it will slow down awareness campaign and targets could not be seen

4. Problems and Challenges

While it is acknowledged for putting in place a good start and basic foundation, challenges on sustainability and dissemination rate still are weighing and summarized as follows.

4.1. Availability of Manure

It is obvious that, after construction of a digester, the farmer requires to feed his digester regularly with required amount of animal manure. Biogas digesters in Africa are usually fed with cattle dung daily. The quantity of manure and the commitment of farmer to entertain digester is a key to ensuring long term operation.

African family size is relatively big consequently big digesters and enough amount of animal manure will be needed to comply with daily gas need. Big digester means more feeding materials and animal heads. This is a big concern for farmers when cattle's breeding is hampered by more difficulties to collect animal feedstock, water and then sustain the cattle healthy and productive. The labor need for acquisition of animal feeding material, collecting of water for mixing with animal feedstock, regular maintenance all have increased the stress to the farmers meaning that the potential biogas users required to pay more investment and operational cost. These are seen as drawbacks to the African biogas and any involvement could take into consideration its long term consequences. Nonetheless, African farmers also didn't pay attention to the use of other agricultural waste materials other than cattle dung as methane raw materials, such as pig manure, poultry dung and crop straw.

4.2. High Initial Investment Cost

Depending on the size of the digester, its location and government subsidy availability if any, a potential client needs to invest in construction of the digester. The farmer also has to avail the labor required for daily operation and maintenance of digester supervision, storage and disposal of slurry. The availability of this labor determines if the digester will be well operational. The initial investment cost is probably the major bottleneck to the adoption of biogas technology in Africa where an important number of African population lives under the poverty line [18].

Considering the total price of digester in selected African countries, the cost of 4 m^3 digesters is estimated at around US$ 1000 in Rwanda, US$ 700 in Cameroun and Kenya, US$ 650 in Tanzania, US$ 600 in Burkina Faso, US$ 560 in Senegal and US$ 550 in Uganda, see **Table 1**. We also need to remember that, the daily gas need increases with family size, consequently the price will also increase. Thus, this 4 m^3 biogas plant sometimes do not match with most of African household family size which means, bigger size and more investment are required.

In this situation, biogas technology seems to be only affordable by the happy few at the top of demand pyramid. To develop biogas sector in Africa requires effort from different stakeholders to establish different working mechanisms, subsidy scheme policies and reliable credit facilities to ease adoption and regional adaptability.

We also have to recall that, financial support to small enterprise and serious individuals to set up effective business operation in the biogas technology seemed to be neglected. The private sector shows deterrence to invest in biogas while input from big Enterprises is somehow lagging behind due to the low incentive profits.

Moreover, lack of flexible community friendly credit scheme to help poor farmers to own digester seems to be another issue, while credit agencies aiming at making profits are often reluctant for such kind of credit. This may lead potential client to delay or even abandon his investment decision. Certainly, there will be an immediate negative effect on the progress of biogas dissemination, if there are no appropriate measures to tackle those kinds of problem.

4.3. Lack of Information Sharing and Recent Research Information on Biogas Technology

A few number of research works on biogas technology can be found on internet, but it is quite difficult to know what is going on at national levels. Lack of data collection, evaluation and information sharing is regarded as a barrier to anaerobic digestion technology in Africa. The numbers of reports for some institutions remain confidential and gathering information action is hampered by some procedures. Furthermore, research engagements are not yet fully adopted by academicians and government institutions sometimes due to lack of funds or roadmap. These actually have negative impact on biogas dissemination and also obstruct joint research programs between developed countries and developing countries.

Thus, the possibility for technological transfer that could rise up the technological mindset and satisfaction of biogas users and implementers will be played down. Despite the existence of a wide range of business oppor-

Table 1. Cost of 4 m^3 digester in selected countries.

Country	Bulk Construction	Plumbing	Appliances	Labor	Other	Total in US$/4$m^3$ digester
Rwanda	521.94	112.51	70.33	226.21	48.09	979.08
Cameroun	410.64	73.08	9.00	205.10	-	697.82
Kenya	359.10	63.54	68.00	174.73	-	665.37
Tanzania	364.39	71.84	50.00	163.16	5.26	654.65
Burkina Faso	300.86	48.09	45.73	144.82	60.98	600.48
Senegal	251.33	51.72	73.17	186.05	22.10	584.38
Uganda	283.99	49.33	37.33	90.00	94.32	554.97

Source: Cost reduction 2010, National Domestic Biogas Program, NDBP-Rwanda.

tunities in rural areas in Africa, experience has shown that local entrepreneurs have not yet taken advantage of such opportunities due to lack of capacity and resources to develop a robust business plan of research works.

4.4. Political and Security Issues

Some assumption pointed out that security threat in Sub-Saharan Africa may be also one of the causes that slow down the biogas technology dissemination. The different regions of Africa shelter internally displaced persons and refugees such as DR Congo, Uganda, Kenya, and Soudan among others. People from unsecured areas are often hesitant to invest in long-term projects. These insecurity problems are sometimes linked with food security crisis that overwhelms economic development at various levels and may cause direct or indirect effect on biogas technology.

4.5. Biogas Technology Pilot Phase Failure

Demonstration and pilot phase in Africa took place about four decades ago but, it is reportedly said that most of digesters constructed during that period showed various malfunctions that disrupted biogas dissemination campaign [19]. The technology required some skills, social acceptance and mind set for reliable operation, which the beneficiaries lacked. Moreover, a lot of biogas plants were individual demonstration plants which were not really wanted by the users, but were more tolerated. Consequently traditional sources of energy continued to be preferred, henceforth the benefits of biogas technology has not been capitalized.

5. Conclusion

The need to benefit from African biomass resources is fully justified by low electric distribution, alarming deforestation and the pressing use of clean energy and sustainable environment. Considering the role, importance and contribution of biogas technology to the welfare of people, especially those with low income and present dissemination rate, there is a wide gap to overhaul. Besides, the biogas dissemination will have to go beyond some hitches like high investment cost, political and security issues together with pilot phase grievances to ensure that marketable biogas technology has been put in place. There is a need to fully engage and speed up dissemination of biogas digesters by designing specific policies, full support and promotion of anaerobic digestion technology. Granting subsidy and supporting rural communities to develop biogas industries may seem as milestone since it would lead to job creation, husbandry industries and finally, improve rural people's livelihood in Africa.

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