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Biogas technology dissemination in Ghana: history, current status, future prospects, and policy significance

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Abstract
Despite numerous benefits derived from biogas technology, Ghana is yet to develop a major programme that will promote the dissemination of biogas plants on a larger scale. This paper reviews biogas installations in Ghana and investigates challenges facing the design, construction, and operation of biogas plants. It further captures the current status and functions of biogas plants as well as the impact of these plants on the people who use them. The study was done by surveying fifty (50) biogas installations, and conducting interviews with both plant users and service providers. From the survey, twenty-nine (58 %) installations were institutional, fourteen (28 %) were household units, and the remaining seven (14 %) were community plants. Fixed-dome and water-jacket floating-drum digesters represented 82 % and 8 % of installations surveyed, respectively. It was revealed that sanitation was the main motivational reason for people using biogas plants. Of the 50 plants, 22 (44 %) were functioning satisfactorily, 10 (20 %) were functioning partially, 14 (28 %) were not functioning, 2 (4 %) were abandoned, and the remaining 2 (4 %) were under construction. Reasons for non-functioning include non-availability of dung, breakdown of balloon gasholders, absence of maintenance services, lack of operational knowledge, and gas leakages and bad odour in toilet chambers of biolatrines. This paper recommends the development of a national biogas programme focussing on three major areas – sanitation, energy, and agricultural fertilizer production; it further supports the development of standardized digester models. The founding of a national body or the establishment of a dedicated unit within an existing organization with the sole aim of coordinating and managing biogas dissemination in Ghana is proposed.

Keywords: National biogas programme, Biogas technology, Sanitation, Energy, Fertilizer.

1. Introduction

Active harnessing and development of renewable energy (RE) sources in Ghana began in the mid 1980s [1]. However, after more than 20 years in the recognition of RE potential in contributing substantially to the energy mix of the country, Ghana still lacks the capacity to developing her own RE sources. In 1997, the Energy Commission (EC) was founded, among other functions, to develop, regulate, and manage RE resources in Ghana. In 2006, the EC developed the Strategic National Energy Plant (SNEP) – a policy document that defined the role of various energy sources, setting target for each within a twenty year span. From SNEP, biomass based energy, apart from the direct use as woodfuel (firewood and charcoal), has been exploited to a very limited extent in Ghana. Woodfuel represent the traditional energy source in Ghana and accounts for 60 per cent of total energy used (Figure 1).

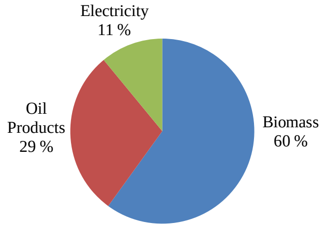

Figure 1. Energy share of fuels in Ghana as at 2006 [2]

Biofuels (biogas, biodiesel, and bioethanol) have not been adequately developed to play a major role in the energy mix of Ghana. For instance, in SNEP, the potential contribution of biogas technology towards the growth of the energy sector was not captured compared to other renewable energy options such as wind and solar. In order to realize a reduction in the share of woodfuel in the national energy mix from 60 % in 2006 to 40 % in 2020 as stipulated in SNEP, there is the need to promote research and development in other renewable energy options including biogas technology.

Biogas (anaerobic fermentation) technology is noted for improving sanitation, generating clean energy, and producing rich organic fertilizer. In China, India, and Nepal, household and institutional biodigesters have gained widespread acceptance. Since 2001, China has disseminated over 2 million household digesters annually; in addition, the Chinese government has supported over 200 large and medium livestock farms to own large and advanced biogas units [3]. From 2001 to 2007, over 18 million households adopted the technology leading to the production of over 7 billion m^3 of biogas; moreover, 87 million tonnes of animal waste were treated by 3,556 biogas plants and more than 300 Clean Development Mechanism (CDM) projects involving biogas power generation, with a total capacity of 1 GW and an annual emission reduction of over 20 Mt of CO_2, were also developed [4].

In India, over 3 million domestic digesters and 3000 community and institutional plants were constructed by the end of 2002 [5], and since 2005, more than 100,000 biodigesters have been disseminated annually [6]. Other successful biogas promoting Asian countries include Nepal, Vietnam, and Thailand.

In Africa, biogas technology dissemination has been relatively unsuccessful. Njoroge [7] attributes the non-progressiveness of most biogas programmes to failure of African governments to support biogas technology through a focused energy policy, poor design and construction of digesters, wrong operation and lack of maintenance by users, poor dissemination strategies, lack of project monitoring and follow-ups by promoters, and poor ownership responsibility by users. Despite the relative stagnation of biogas programmes in Africa, the future prospects are encouraging. Aside energy (cooking and lightning, fuel replacement, shaft power), several biogas plants in recent years have been constructed as environmental pollution abatement system in several countries including Ghana, Kenya, Tanzania, Rwanda, Burundi, and South Africa [8]. Between 4000 – 5000 digesters is estimated to have been built in Tanzani [9](Marree et al, 2007), while Kenya is said to have disseminated about 2000 digesters as at October 2007 [10]. In Ghana, about 200 digesters have been disseminated [11].

2. Biogas technology dissemination in Ghana

2.1 Before 1990

Interest in biogas technology in Ghana began in the late 1960s but it was not until the middle 1980s did biogas technology receive the needed attention from government. Dissemination programmes before the mid 1980s focused on the provision of energy for domestic cooking. Most plants, however, collapsed shortly after duration of project due to immature technologies and poor dissemination strategies [12]. In order to resuscitate the technology, a cooperative agreement between Ghana and China led to the

construction of a 10 m^3 plant at the Bank of Ghana (BoG) cattle ranch in the Shai Hills and the start of the Appolonia Household Biogas Programme in 1986 [12, 13].
The Appolonia Household Programme focused on energy for cooking for cattle-owning households at Appolonia, a rural community in the Greater Accra region [11, 12, 13, 14 and 15]. A total of nineteen fixed-dome digesters comprising six 15 m^3 and two 30 m^3 Deenbandhu digesters, and eight 10 m^3 and three 25 m^3 Chinese dome digesters were constructed by engineers from the Ministry of Energy (MoE) and the Institute of Industrial Research (IIR) [11]. This was followed by the construction of two household demonstration plants at Jisonayilli and Kurugu, all in the Northern Region in 1987, under the aegis of the United Nations Children Fund (UNICEF) [13]. Apart from the Ministry of Energy, biodigesters were also been promoted by Dr. Elias Aklaku, an engineer and a senior lecturer at the Agricultural Engineering Department of KNUST, mostly with support from the German Agency for Technical Cooperation (GTZ).

2.2 From 1990 to 1999

In June, 1992, the Ministry of Energy commissioned the first large scale community-based biogas plant in Appolonia. The Appolonia Integrated Rural Energy Project was aimed at providing street lighting and electricity for small load appliances for all the households in the community. Cow dung and human excreta were used to feed the digesters, and the gas produced was used to run a 12.5 kVA generator which provided power for street and home lighting, while the bio-slurry was used for agriculture [11, 14]. The project experienced several setbacks and did not performed satisfactorily as planned due to multiplicity of factors including feedstock availability problems, distance of kraals (1/2 km) from the community, maintenance problems, and uncooperative attitude of some of the inhabitants.
Problems also arose in the utilization of the digested slurry as farm manure. In the initial stages, the liquid organic fertilizer from the plant was successfully used on farms even though farmers complained of intense labour involved in carrying liquid fertilizer from the plant site to their farms. Another major problem was the drudgery involved in collecting dung from kraals situated hundreds of meters away from the community [16]. Furthermore, Fulani herdsmen prevented women from collecting dung from the kraals on the basis that women could cause pregnant cows to give premature births [12].
Apart from the Ministry of Energy, the Catholic Secretariat and GTZ have been involved in biogas promotion in Ghana. The Secretariat financed the construction of biogas plants at the Catholic Mission at Kaleo in the Upper West Region [17]; and in three Catholic hospitals – Holy Family and St. Dominic hospitals in the Eastern Region, and Battor hospital in the Volta Region – between 1994 and 1995 [11, 13]. Some biogas projects financed by GTZ has been disseminated to treat slaughterhouse waste at Ejura and KNUST in the Ashanti Region [11].
From 1993 and beyond, direct involvement of the MoE in biogas dissemination slumped mainly due to lack of donor support and unfulfilled expectations of the Appolonia projects. Attempts were made to rekindle the involvement of government in 1996 when the MoE financed a study aimed at assessing biogas resources in Greater Accra, Volta, and the three Northern Regions. This study was intended to be the first step in planning and developing a national biogas programme. Ampofo [17] estimated a potential of 88,144 m^3 of biogas a day which could generate about 193 GWh of energy annually. Ampofo [17] did not estimate the quantum of liquid fertilizer that could be generated but Bensah and Brew-Hammond [16] have shown that an amount of 360,000 tonnes of liquid organic fertilizer could be produced yearly, which would be capable of fertilizing about 70, 000 hectares of irrigated farmland or 140, 000 hectares of dry farmland. Intriguingly, after more than a decade since the study was completed and the report submitted to the MoE, the Ministry has shown no interest in developing a national biogas programme. Furthermore, the Institute for Industrial Research, a parastatal organization involved in biogas digester dissemination, has not been able to influence policy makers into giving the necessary support to the biogas industry in Ghana.

2.3 From 2000 to date

According to Edjekumhene *et al* [15], barriers that have plunged biogas dissemination in Ghana include unfavourable policies, non-availability of feed materials, poor financing arrangements, problems with social acceptance, absence of market, and lack of information. Following the low involvement of biogas projects by government, a number of private biogas companies have marketed the technology on purely business grounds, and mainly based on the ability of biogas plants to improve sanitation [8, 13 and 16]. The two leading companies – Biogas Technology West Africa Limited and Beta Civil Engineering

Limited – have been constructing brick-based fixed-dome and concrete-based Puxin digesters, respectively.

According to SNV (2007), Ghana has the potential to realize the dissemination of about 270 thousand domestic biogas plants. This is contained in the Biogas for Better Life (B4BL) initiative for Africa – an ambitious programme conceived by developing partners of Africa and launched in Nairobi in May 2007. The major aim is to combat poverty by providing over two million households in Africa with biogas plants, with collateral benefits of improved family health through reduction of indoor pollution and drudgery involved in firewood collection and usage [18]. Other objectives of the initiative include the establishment of more than 800 private biogas companies and 200 biogas appliance manufacturing workshops and the construction of one million biotoilets. In a study to assess domestic biogas potential from cow dung in the three Northern and Ashanti Regions, KITE [13] estimated a technical potential of 80,000 household biogas installations and a market potential (estimated based on the ability and willingness of users to pay) of about 8,000 (8 % of 80,000) plants. According to KITE [19], households have not shown much interest in using biogas in their kitchen or the digested slurry in their farms; thus, biogas technology has been disseminated mostly in institutions such as schools, hospitals, prisons, and slaughterhouses.

3. Current state of biogas technology in Ghana

A survey of 50 biogas plants was conducted in order to ascertain the true state of biogas technology in Ghana. Field visits to biogas installations were conducted between June, 2008 and February, 2009. The sample size (50 plants) was determined from the population (100 known biogas plants as captured in a survey by KITE [13]) using stratified and convenience sampling techniques. The population was stratified into seven strata, with each stratum representing the number of known plants constructed by each of the seven major biogas service providers. The sample size was selected from the strata using convenience sampling. The survey technique used included direct observation of the various components of biogas installations, and structured and unstructured open-ended interviews with both users and experts.

Major challenges encountered during the field visits included inadequate funding, difficulty in locating biogas plants in cities, towns and villages where they have been disseminated, inability of service providers to provide full records of the location and number of plants constructed, and the absence of a national body that keeps track of developments in the industry. All the aforementioned challenges affected the smooth gathering of data and information; nonetheless, the depth of data gathered was enough to make generalizations on biogas technology dissemination in Ghana.

Figure 2 shows the number of installations built over the last three decades as captured by the survey.

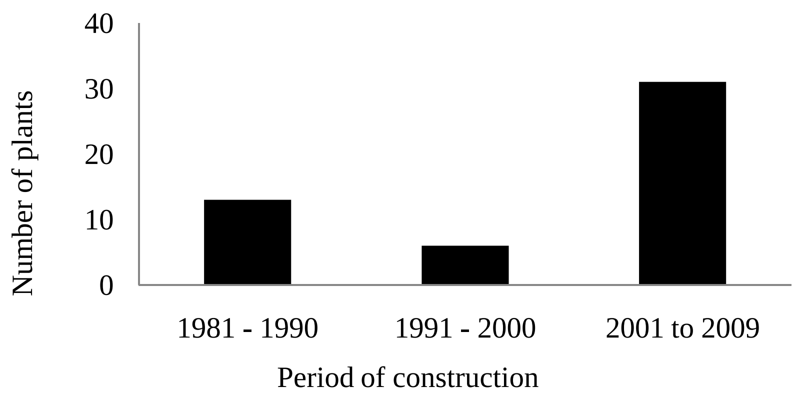

Figure 2. Period of construction of surveyed plants

The 1981-1990 period saw the implementation of the domestic biogas programmes at Appolonia and Okushibli – two major cattle-rearing communities in Greater Accra Region. In 1992, the Appolonia Electricity programme was commissioned; in addition, biogas plants were built in three hospitals at Battor, Nkawkaw, and Akwatia.

The relatively large number of plants disseminated from 2001 to 2009 can be ascribed to the founding of BTWAL, the largest biogas company in Ghana, by John Idan in 2000. Some of the biogas installations disseminated by BTWAL can be found at the Golden Jubilee House (Presidential Palace) in Accra, Central University College – Miotso campus (Figure 3a), and Tamale Teaching hospital. Another major factor was the decision by Beta Civil Engineering Limited – a construction company – to disseminate biogas plants; the company has constructed over 40 Puxin digesters in Ghana and a few in Nigeria since 2006. A Puxin digester disseminated at Hebron prayer camp in Ga-west district of Greater Accra Region is shown in Figure 3b.

(a) (b)

Figure 3. (a) Three 100 m^3 fixed-dome digesters at CUC, Miotso, November, 2008, and (b) Four 10 m^3 Puxin digesters at Hebron Prayer Camp, Hebron, November, 2008

Apart from the aforementioned companies, the other biogas service providers have not been very active; for instance, IIR (Institute of Industrial Research) has disseminated a few biotoilets at various locations in Ghana between 2004 and 2006, in addition to a 200 m^3 plant at Ankarful Prison in the Central Region. Our of 50 installations studied, 22 were in good condition, 10 were functioning even though some defects (including deteriorated gasholders, gas pipelines and appliance) were observed, and 14 were broken-down. This observation is shown in Figure 4. The oldest operating plants were found at the St. Dominic Catholic hospital which has been functioning uninterrupted for 15 years despite intermittent problems with the gas delivery systems.

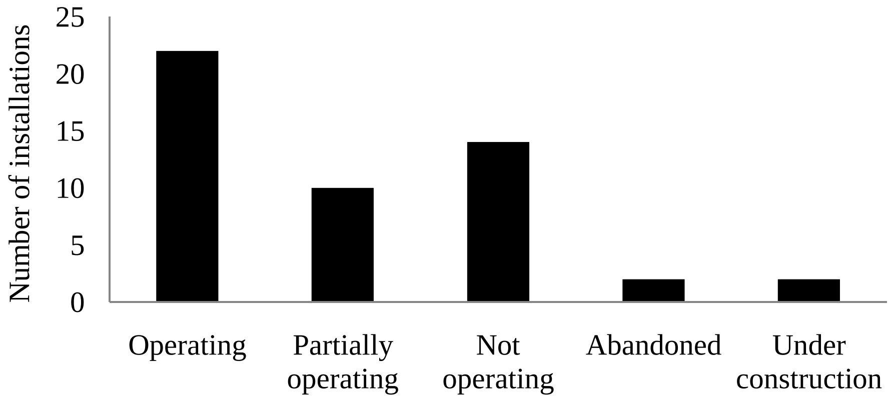

Figure 4. Functional status of surveyed installations

More than 50 % of surveyed installations were institutional plants (Figure 5) while educational and health institutions accounted for 55 % of the 29 institutional units (Figure 6). It was also observed that majority of plants (76 %) had been constructed mainly in the cities for the treatment of human excrement from flushing toilets. At Obuasi, Anglogold Ashanti Limited has adopted biosanitation technology in treating sewage from her estates and other facilities including the company's hospital. With the exception of the plants constructed under the Appolonia Electrification Programme, all community plants surveyed were biolatrines (pit latrines attached to biogas plants).

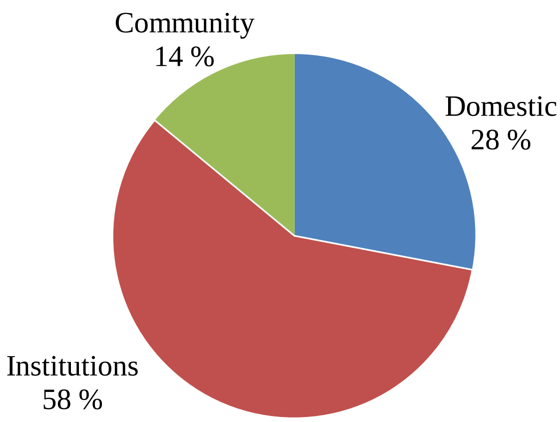

Figure 5. Surveyed installations grouped into institutional, community, and domestic plants

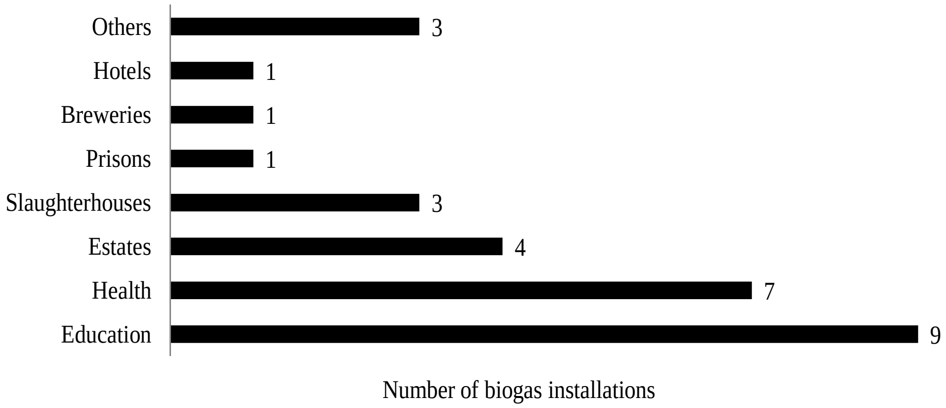

Figure 6. Institutions using biogas systems

The domestic installations surveyed include six plants built in 1987 at Appolonia and five plants constructed at Okushibli in 1990; most of these installations broke down between 1996 and 2001 due to several challenges including non-availability of cow dung, availability of woodfuel, deterioration of gas stoves, and lack of follow-up services by biogas service providers. Figure 7 shows the remains of biogas plants at Apollonia (a) and Okushibli (b). After the Appolonia Electrification programme in 1992, no community installation digesting cow dung has been constructed due to the high cost of biodigesters, reduction of financial support from GTZ, and the absence of specific programmes designed to promote community digesters in cattle-rearing terrains in Ghana.

3.1 Motivation for using biogas plants

As part of the survey, biogas users were asked to state the main motivational factor that influenced them to adopt biogas technology. The response is shown in Figure 8. It is obvious that most users of biogas units in Ghana patronize the technology solely on the ability of biodigesters to treat nightsoil, thereby replacing septic tanks.

Biogas service providers have achieved success in promoting the technology as the most efficient and cost effective way of treating sewage despite the high cost of biodigesters. There are a number of sewage rehabilitation projects where old sewage handling systems such as septic tanks and Kumasi Ventilated Improved Pits (KVIPs) are gradually making way for biosanitation interventions.

Apart from improving sanitation, biogas plants are also known for generating energy and organic fertilizer. It appears that the ability of biogas plants to produce organic fertilizer for agriculture has not been given priority by service providers in Ghana. Most users of biogas systems are content with the performance of the plant as long as the plant treats their sewage without any problem. The low level of interest to disseminate biogas plants focusing on energy and agriculture can be attributed to lack of a concerted programme targeting the dissemination of biogas plants among livestock farmers in Ghana, majority of them living in rural communities and with limited/no access to agricultural inputs and modern energy services. These are people who will value the products of the biogas plant and therefore make use of both the gas and the fertilizer.

(a) (b)

Figure 7. (a) Remains of a Chinese dome at Applonia, February, 2009, and (b) A broken-down Deenbandhu digester at Okushibli; February, 2009

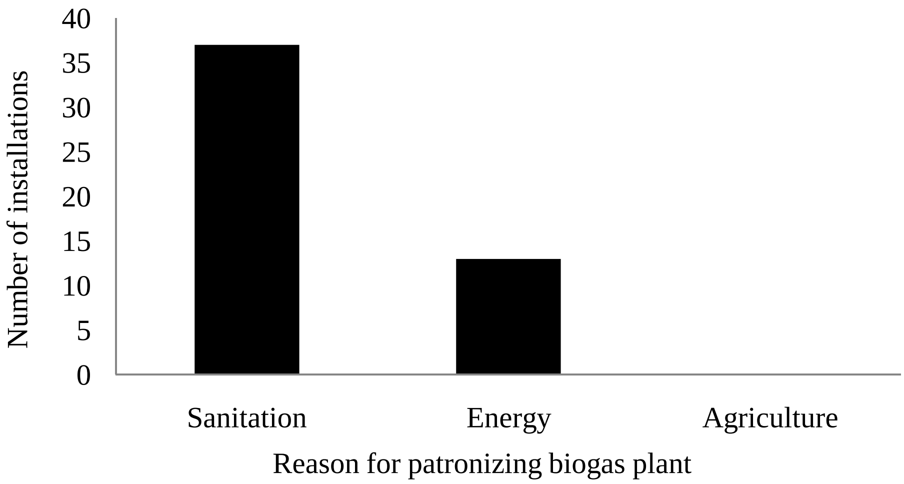

Figure 8. Main factor motivating usage of biogas plants

The major problem, however, lies with the inability of rural cattle farmers to afford the full cost of biogas plants which are very expensive in Ghana. For example, in 2009 the average investment cost of a 10 m^3 digester ranged from GH¢ 4,000 to 6,000 ($ 2,800 and 4,200). These figures are far above the financial capability of the rural farmer and it is imperative that special microcredit schemes are developed as a means of promoting biogas plants among poor farmers.

3.2 Feed material used in biogas plants in Ghana

It has been shown already that the majority of households and institutions patronize biogas plants mainly as waste (nightsoil) treatment systems and as replacement for septic tanks. Most sanitary plants are either designed to treat nightsoil from flushing toilets or nightsoil from KVIP toilets. Apart from nightsoil, slaughterhouse wastes have also been treated using biogas plants. However, due to the high fibre content of slaughterhouse wastes, most plants constructed to handle the waste have broken down due to the formation of scum, poor operation and maintenance, and inappropriate siting of plants, as observed at

Tepa slaughterhouse (Figure 9). Scum is formed when fibrous feed materials accumulate at the top of the slurry, thicken and harden, thus obstructing the flow of gas into the gasholder. The gas is then forced to escape into the atmosphere via the inlet and outlet pipes of the digester. Figure 10 gives an idea about the composition of feeding materials used in biogas plants in Ghana.

Figure 9. A water-jacket floating-drum plant at an abandoned slaughterhouse at Tepa in Ahafo-Ano north district of Ghana, September, 2008

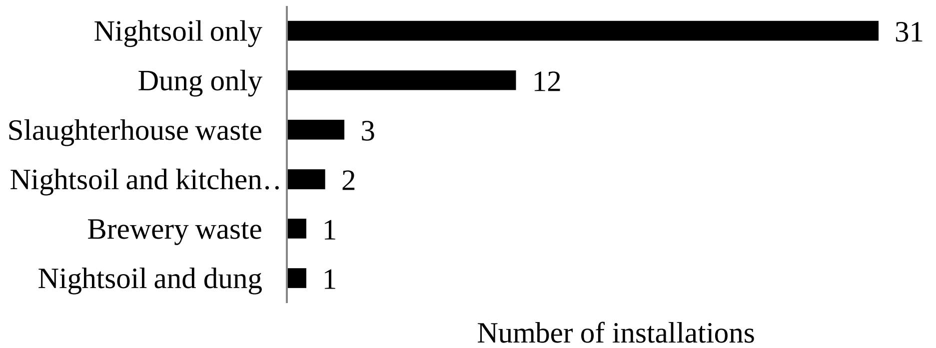

Figure 10. Feed materials used in biogas plants in Ghana

3.3 Types and sizes of plants disseminated

With the exception of an Upflow Anaerobic Sludge Blanket (UASB) plant (Figure 11) constructed at Guinness Ghana Breweries Limited in Kumasi, most of the plants surveyed are either floating-drum or fixed-dome digesters. All the floating-drum digesters are of the water-jacket type with a spherical digester (BORDA model) while the gasholders are fabricated from mild steel apart from two glass-fibre gasholders at Tepa slaughterhouse and Holy Family hospital, Nkawkaw, and a high density polythene gasholder at GIMPA (Ghana Institute of Management and Professional Administration). Despite the merits of the floating-drum digester, the fixed-dome digester has found favour among most biogas service providers in Ghana, accounting for more than 80 % of installations sampled. Figure 12 highlights the main types of biodigesters found in the survey. Fixed-dome plants are less expensive compared to floating-drum digesters. Fixed-dome models disseminated by the various companies are the CAMARTEC (Centre for Agricultural Mechanization and Rural Technology) model, the Deenbandhu model, the Chinese dome model, and lately the Puxin digester. It should, however, be emphasized that most of the biogas companies have also disseminated designs with slight variations from the aforementioned models just to suit the topographic conditions of a particular area.

The sizes of surveyed plants (digester and gasholder as one unit) range from 10 to 100 m^3. Most household and institutional plants disseminated have volumes of 10 m^3 and 50 m^3 respectively. Series (tandem) digesters have also been constructed. The most important criterion in sizing the digester is to be able to meet the minimum retention time; this is very important if the plant is to treat human excreta. Before the designer settles on the digester volume to use, he needs to consider factors such as daily availability of feed material and the retention time. The choice of the retention time in turn is influenced by the type of feed material, the digestion temperature, the plant type, and financial capabilities of the user, among others. Table 1 gives the retention times used by some major biogas companies in Ghana.

Figure 11. An 800 m^3 UASB bioreactor at Guinness Ghana Breweries Limited, Kumasi, August, 2008

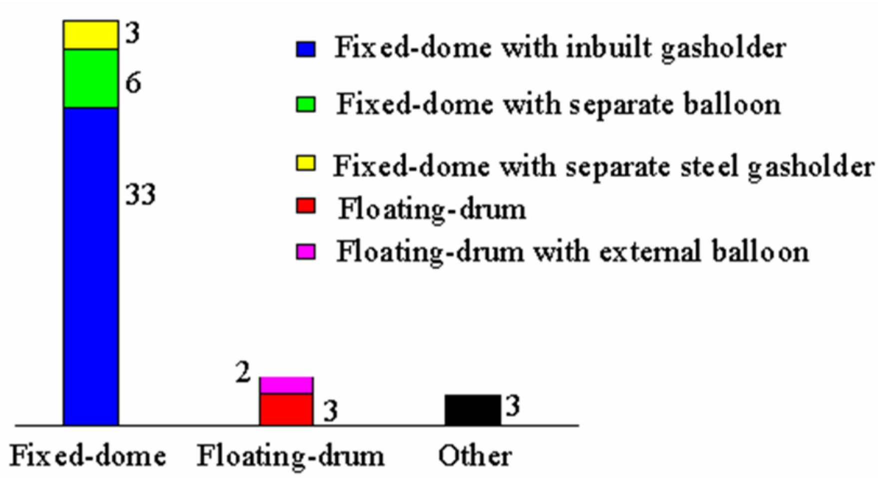

Figure 12. Main types of biodigesters surveyed

Table1. Retention time used by some biogas service providers under mesophilic (25 – 30 ^{0}C) conditions

Biogas service provider	Retention time [days]
Biogas Technology West Africa Limited (BTWAL)	30 – 60
Biosanitation Company Limited (BCL)	20 – 30
Beta Civil Engineering Limited (BCEL)	15 – 30
Institute of Industrial Research (IIR)	30 – 40
Biogas Engineering Limited (BEL)	30 – 60

If a biogas plant is designed to treat waste such as nightsoil, then the retention time should be long enough to allow for effective treatment of the waste, such that the effluent do not pose a health threat to the environment. The average retention time must be high enough to enable the degradation of the biomass; on the other hand, it must be kept as low as possible, because a high retention time means a high investment cost. Considering the high pathogen levels of human excreta, it is obvious that retention time of 30 days or less may not be adequate to kill enough pathogens under mesophilic digestion.

According to Sasse *et al* [20], plants less than 30 m^3 should not be used for treating blackwater from flushing toilets because of the danger of reducing the retention time. It has also been recommended that a retention time between 70 and 80 days is needed for plants handling nightsoil, in order to ensure the reasonable destruction of pathogens [21].
As seen in Table 1, some service providers use a retention time lower than 30 days for designing plants to digest nightsoil, which is inappropriate and should be a matter of concern to environmentalists. However, BCL, BCEL, IIR and BTWAL have been installing systems that have post-treatment facilities ranging from filtration tanks to solar concentrators for further treatment of the effluent. There is still the need to conduct a thorough analysis of effluent samples to determine the safety of the 'treated' effluent.

3.4 Tandem digesters

Tandem plants have two or more digesters working in series such that the effluent of one digester becomes the feed material for the second digester and so on. They may comprise two or more of the same type of digester or different digesters working together as one unit. The main advantages of tandem digesters (two-stage systems) over one digester (one-stage) systems include higher biomass conversion efficiency, higher methane concentration in the gas, better process reliability and stability, and high quality organic fertilizer [22]. Despite the aforementioned merits, tandem systems are not widely disseminated worldwide because they are expensive and difficult to engineer, construct and operate [23, 24 and 25].
In Ghana, Tandem plants have been constructed to treat sewage by BTWAL, BCEL, IIR, and BCL. Most common tandem digesters found in Ghana consist of two series digesters except the plant at Pope John's Seminary in Koforidua and Hebron Prayer camp at Hebron (Figure 3b), where BCEL has constructed systems comprising four 10 m^3 Puxin digesters. The main problem with tandem digester designs used by service providers in Ghana pertains to the inappropriate way of connecting adjacent digesters via a horizontal pipe near the base of the digesters. This arrangement leads to inefficient digestion since the second digester merely serves as an expansion chamber of the first digester rather than serving as a digester on its own. Moreover, digestion in the first digester will also be inefficient as slurry flows freely into the second digester. Figure 13 shows the layout of tandem digesters as used by biogas service providers as opposed to the recommended layout.

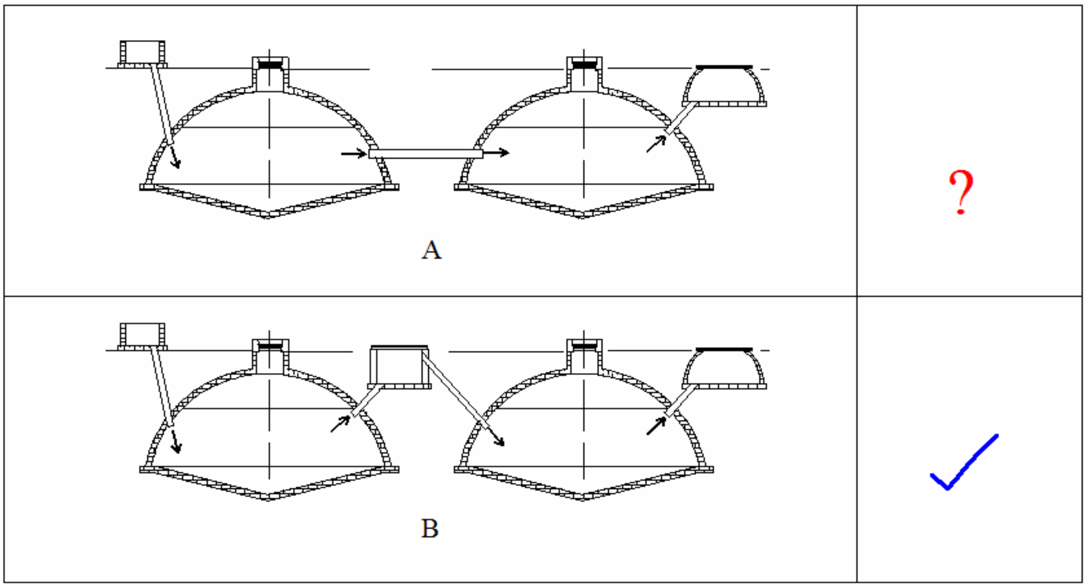

Figure 13. (A) Tandem digester layout used by BTWAL, BCEL, and BCL, and (B) Appropriate and recommended layout [23]

Tandem plants require a lot of calculations before designing them. The designs with horizontal pipes connecting adjacent digesters can work efficiently only if valves are placed at vital points to control the movement of fermentation slurry from one digester to another, and also the flow of effluent from the last digester. However, such an arrangement will be labour intensive in terms of operation and will also require skilled attendants. The correct arrangement of tandem plants, as seen in Figure 13B, is to connect a pipe near the base of the first digester to an expansion chamber which empties into the next digester. This arrangement ensures both plants function as fixed-dome systems, and ensures the effluent from the last digester undergoes thorough digestion.

3.5 Community biosanitation projects – Biolatrines (biotoilets)
A total of 9 biolatrines were surveyed (Table 2). Of the 9 biolatrines visited, four were not functioning due to design and operational challenges. The major problem with the design of biolatrines pertains to the connection between the toilet seat and the inlet pipe of the digester. If faeces got stucked to the inlet pipe, aerobic digestion takes place and bad odour is generated. This is believed to be the cause of breakdown of biolatrines at Kaase and Parkoso in the Ashanti Region. Even though, experience from the Kaase and Parkoso project have led to improved designs, there are still problems with gas leakage through the inlet pipe into the toilet house, as observed in the biolatrines at Abeman, Asokore-Mampong, Kotoku, and Tamale West hospital.

Table 2. Profile of visited biolatrines

Location of biolatrine	Service provider	Status	Water usage	Problem
1. Abeman community (Greater Accra)	BTWAL	Operational	Regular	Gas leakage Fire hazard
2. Parkoso community (Ashanti Region)	TIE*	Not operational	Occasional	Gas leakage Bad odour
3. Asokore Mampong community (Ashanti)	TIE	Operational	Regular	Bad odour
4. Kaase community (Ashanti Region)	TIE	Not operational	Occasional	Bad odour
5. Tamale West Hospital (Northern Region)	BTWAL	Operational	Regular	Gas leakage
6. St. Martins Senior High School (Eastern Region)	-	Operational	Regular	Choked inlet pipe
7. Gambaga community (Northern Region)	IIR	Not operational	Occasional	Bad odour Gas leakage
8. Mankraso community (Ashanti Region)	IIR	Not operational	Occasional	Digester full
9. Kotoku community (Greater Accra)	IIR	Operational	Occasional	Gas leakage

* Technology for Improved Environment, now defunct

Another major challenge concerns the mode of operation of the biolatrine. Even though, biolatrines are designed to handle faeces with little or no water, they rather perform efficiently if water is frequently used to flush the faeces. Thus, most biolatrines having water reservoirs enable users to flush the toilet with water after use. The use of water regularly avoids the occurrence of aerobic decomposition of faeces entrained in the inlet pipe of the digeste. From the survey, two biolatrines (Figure 14) were found to have been disseminated very close to rubbish dumps.
Caretakers attributed low patronage of these biotoilets to unbearable stench from the dump. It was also observed that communities benefiting from biolatrine projects were not involved in the planning and implementation of the projects. The absence of interaction between community members and service providers on the functions of biolatrines has created ignorance among communities on the importance of biolatrines in improving sanitation and health.

(a) (b)

Figure 1. Biolatrines engulfed in garbage at Mankranso (a) and Asokore-Mampong (b), December, 2008

3.6 Gas utilization

Due to low level of dissemination of plants handling cow dung, especially after the Appolonia Electrification project in 1992, the focus of biogas technology shifted from provision of energy (use of gas) to improvement in sanitation (treatment of waste). This development has created a situation where most plants have been constructed without adequate arrangements for the usage of the gas thereby leading to gas leakage.

Gas leakage is a serious problem. In addition to the discomfort and health implications caused by inhalation of the gas, there is the potential of fire outbreak since mixtures of biogas and air in certain concentrations (6 – 12 % biogas) could be explosive and may cause damage to human life and property. Moreover leakage of biogas, which contains about 60 % methane, into the atmosphere offsets environmental gains made by putting up the plant. Out of the 32 functioning plants studied, 12 of them experienced gas leakage problems. At both the Holy Family and the St. Dominic hospitals, the balloon gasholder was completely deteriorated and gas leaked freely into the atmosphere (Figure 15). Likewise, gas produced by most biotoilets was not used neither was it flared.

(a) (b)

Figure 15. Deteriorated balloon gasholders at Holy Family hospital, Nkawkaw (a), June, 2008; and St. Dominic hospital, Akwatia (b), February, 2009

Gas flaring is regularly done in a few locations, including the biogas plants financed at AngloGold Ashanti in Obuasi, where caretakers have been trained to flare the gas at regular periods in order to avoid high pressures within the digester. Gas usage pattern of surveyed plants is shown in Figure 16.

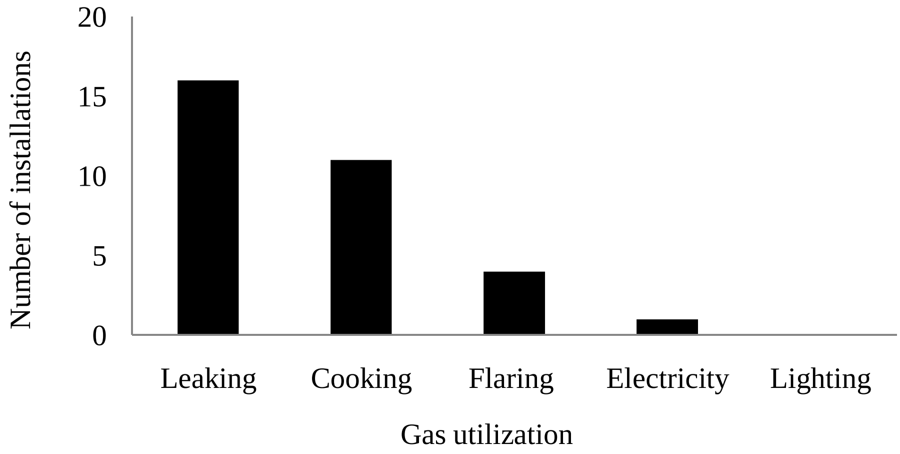

Figure 16. Status of biogas usage in surveyed plants (based on the number of plants functioning fully or partially)

3.7 Effluent (digested slurry) utilization

Biogas plants built with the ultimate aim of generating organic fertilizer are rare in Ghana. The digested slurry is not seen as a resource and most plants discharge their effluent into the surrounding bush or the public drain (Figure 17). Some plants built by BCEL and BTWAL have systems designed to pump the treated effluent for reuse in flushing toilets. The major concern pertains to the safety of the effluent discharged into the public drain. There is the need to conduct a comprehensive analysis of samples of the effluent in order to determine the efficiency of the digestion process of sanitary plants in Ghana.

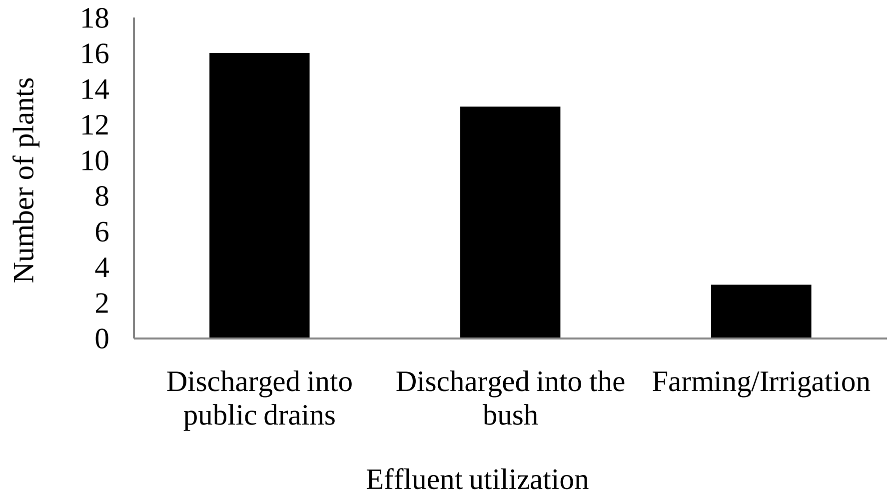

Figure 17. Status of effluent usage in surveyed plants (based on the number of plants functioning partially or fully)

The effluent from biolatrines is not used because of cultural attitude towards the use of human excreta as manure. In a study to assess the performance of biogas technology in Tanzania, Marree *et al* [9] advocates for the use of the effluent from biolatrines as fertilizer in the cultivation of fodder grass. This approach, if adopted in Ghana, will eliminate the stigma regarding the use of human manure in agriculture. Moreover, there is also the need to design and promote programmes that target farmers practicing mixed farming where the effluent can be easily and appropriately used as organic fertilizer.

3.8 Operation and maintenance

A biogas plant may be well designed and constructed but still fail to perform efficiently if it is operated wrongly. Poor operation and maintenance could lead to the collapse of the plant. In a typical plant, good operational activities include, inter alia, daily feeding, cleaning of stoves and other appliances, checking of gas leakages especially at pipe joints and gas valves, and inspection of balloon gasholders. A well engineered plant will function properly as long as these tasks are performed reliably.

The lack of skilled attendants of biogas plants may have contributed more than any factor to the breakdown of most biogas plants in Ghana. It was observed that users of biogas plants have little or no knowledge of the functions of the biogas plant. In addition, users were not sufficiently educated by the service companies. Of the 50 plants visited, only the installations (3 out of 24 plants were visited) at Anglogold Ashanti Limited were monitored daily by a trained engineer (caretaker); this has ensured continuous operation of the plants since 2001.

Biogas plants disseminated in the Catholic hospitals visited have received some level of maintenance; caretakers of the plants had frequently repaired plant components such as the digester, the mixing tank, the expansion tank, and the steel gasholder in floating-drum plants. Unfortunately, balloon gasholders were found deteriorated at St. Dominic and Holy Family hospitals at Akwatia and Nkawkaw, respectively; moreover, gas appliance were not been used since the gas escapes freely into the atmosphere through holes on the balloon.

Other notable maintenance problems were found in biotoilet systems. Service providers do not spend enough time to take users through the rudiments and the functions of various components of the biogas plant. Broken down plants were not repaired because owners were reluctant to spend additional financial resources on the upkeep of plants; this makes the floating-drum digester especially unfavourable due to the regular maintenance of the steel drum.

Follow-up services were almost nonexistent. Service providers attributed this to the unavailability of funds to carry out follow-up programmes.

4. Conclusion

The prospects of biogas technology in Ghana is encouraging. The fact that biogas service providers have been able to market the technology to individuals and institutions forebodes a good future for the technology. Despite the lack of support at the national level, Ghana’s biogas sector has chalked some successes including:

- Involvement of over ten service providers that have promoted the technology solely on business grounds ensuring that the technology thrives with or without government/donor support;
- Dissemination of a good number of functional plants (about 65 % of sampled installations) that have helped to mitigate sanitation problems especially in urban and peri-urban communities;
- Creation of job opportunities through construction of biogas plants and manufacture of local biogas appliances. According to KITE [13], BTWAL at the end of 2007 had a permanent workforce of 148 including engineers, accountants, plumbers, and masons;
- Promotion of biogas plants in institutions such as schools, hospitals, prisons, hotels, orphanages and real estates. This is gradually making biogas technology acceptable for the treatment of sewage in most institutions in Ghana; and
- Promotion of advanced systems such as UASB in the treatment of industrial waste as seen in Guinness Ghana Limited in Kumasi. Moreover, oil palm processing companies such as Ghana Oil Palm Development Corporation (GOPDC) are also considering the adoption of advanced anaerobic fermentation systems for the treatment of wastewater.

There are some challenges that must be tackled holistically in order to ensure a sustainable future of biogas technology. Though Ghana has no national biogas programme, emergent global challenges such as Climate Change and dwindling oil reserves, incidence of extremely poor sanitation in rural, peri-urban and urban Ghana, poor waste disposal practices, rapid loss of vegetation cover, and prevalence of sanitation-induced ailments in health centres would catapult the development and promotion of interventions such as biogas technology. This assertion is evidenced by the development of Renewable Energy Policy and Regulatory Framework – a document expected to catapult the commercialization of renewable energy resources including biogas technology in Ghana [26].

5. Recommendations

The following recommendations, if given adequate consideration, would go a long way to laying down a solid foundation for the progress of biogas technology in Ghana.

5.1 Development of a national programme on biogas technology

There is the need to develop a national biogas programme with a three-pronged focus: agriculture (organic fertilizer production), sanitation, and energy (Figure 18). This national initiative must have distinct programmes for both domestic and institutional plants. Promotion of farm plants among livestock farmers or those interested in improving their yields will encourage the utilization of digested slurry in agriculture and reduce the dependence on imported inorganic fertilizers. The gas generated could be used for cooking, water heating, and lighting.

Large-scale dissemination of sanitary plants will improve hygiene in both urban and rural areas. Replacement of KVIPs with well-engineered biotoilets will ameliorate sanitation problems experienced in public toilets especially in communities where water is scarce. Moreover, the incidence of excreta-related diseases such as dysentery and cholera will be substantially minimized since micro-organisms that cause these diseases are eliminated during the anaerobic digestion process. Large-scale local industries such as oil palm processing and brewing companies generate large volumes of wastewater that pollute the environment when discharged untreated or partially treated. The use of anaerobic fermentation systems in the treatment of industrial wastewater will reduce pollution and improve the quality of the environment.

For the programme to be successful, government must provide funding to support biogas training and microfinance programmes targeted at social groups with high prospects for adopting biogas technology such as farmers in the three Northern Regions.

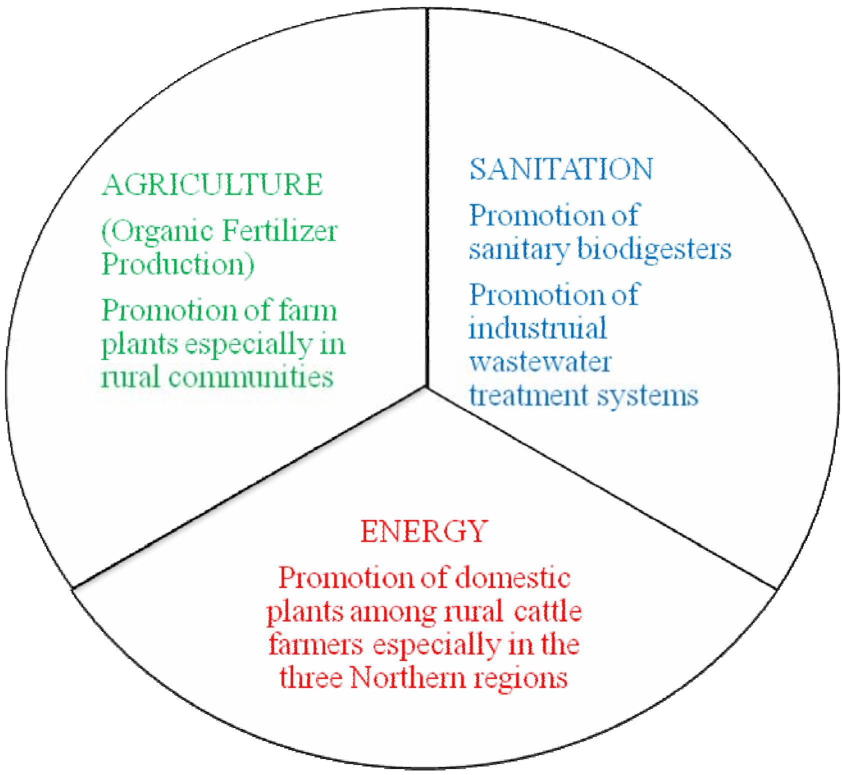

Figure 18. Proposed three-pronged approach for future biogas dissemination programmes in Ghana

5.2 Formation of a national biogas promotion body

From the experience of biogas technology dissemination in developing countries such as Ghana, Tanzania, China, India, and Nepal, it is obvious that biogas promotion cannot be left in the hands of private companies alone. The success story of the technology dissemination in China, India, and Nepal can be partly attributed to the direct involvement of the State through special national or parastatal bodies empowered to lead the campaign in biogas dissemination.

There is therefore the need for Ghana to either set up a national body that is solely responsible for the promotion of biogas technology, or establish a dedicated unit within one of the existing energy organizations for the same purpose. The body or dedicated unit must, among other functions:

- Ensure that biogas (anaerobic digestion) technology is fully considered in Energy, Sanitation, and Agricultural policy of Ghana;
- Develop specific programmes focusing on sanitation, energy, and agriculture;
- Develop programmes specific to the needs of a particular Region or community in Ghana – for example, any major dissemination programme targeting farmers in the three Northern Regions must include the construction of water storage systems as part of the plant;
- Develop sound business model based on public-private-partnership as a way of promoting the technology especially among household systems;
- Identify and involve all stakeholders in disseminating the technology – potential stakeholders in Ghana include public institutions such as Ministry of Energy, Ministry of Agriculture, Ministry of Environment, Science, and Technology (MEST), Environmental Protection Agency (EPA), GRATIS (Ghana Regional Appropriate Technology Industrial Service) Foundation, (Community Water and Sanitation Agency (CWSA), Energy Commission, and Metropolitan, Municipal and District Assemblies; biogas service providers; research institutions such as the Institute of Industrial Research and The Energy Centre - KNUST, international NGOs such as GTZ and SNV; and local NGOs such as Centre for Environment, Energy and Sustainable Development (CEESD) and Kumasi Institute of Technology, Energy and Environment (KITE);
- Develop training programmes for engineers, artisans, technicians, and all professionals involved in biogas dissemination in Ghana;
- Develop standardized biodigesters and quality control standards; and
- Develop CDM projects for which Certified Emissions Reductions could be earned.

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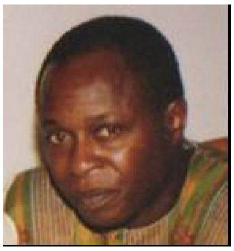

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