PARTNERS FOR INNOVATION

Institutional biogas in Ghana

Technically feasible, economically viable and socially and environmentally desirable;
It is recommended to set-up a National Institutional Biogas Programme to capture all benefits.

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Client: Ghana Energy Commission, Ms Paula Edze
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Cover photos, top row: 'Construction of brick biogas domes'; left photo SNV, middle and right photos projects from Biogas Technologies Africa Limited
Cover photos, bottom row: Gasholder at KITA (Kumasi), programme against using wood fuel (Anglican School, Kumasi) and biogas installation at Wisconsin University (photos E. Hanekamp)

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Definitions and abbreviations

ABPP	Africa Biogas Partnership Programme
ACP	African, Caribbean and Pacific countries
BCEL	Beta Construction Engineers Ltd
BEL	Biogas Engineering Limited
BTAL	Biogas Technologies Africa Ltd
CAP	Country action plan
CEESD	Centre for Energy, Environment and Sustainable Development
CSF	Climate Support Facility
CO_2	Carbon dioxide (a greenhouse gas)
CSIR	Council for Scientific and Industrial Research
EC	Energy Commission of Ghana
EPA	Environmental Protection Agency
EU	European Union
GEF	Global Environmental Facility
GES	Ghana Education Service
GHS	Ghana Health Service
GPS	Ghana Prisons Service
GHC	Ghana Cedis
GHG	greenhouse gas
GIZ	German Development Organization
GSGDA	Ghana Shared Growth Development Agenda
IIR	Institute of Industrial Research
KIST	Kigali Institute of Science and Technology
KITA	Kumasi Institute of Tropical Agriculture
KITE	Kumasi Institute of Technology and Energy
KNUST	Kwame Nkrumah University of Science and Technology
kt	1,000,000 kilograms
KVIP	Kumasi Ventilated Improved Pit
LPG	Liquefied Petroleum Gas
MESTI	Ministry of Environment, Science, Technology and Innovation
MoEP	Ministry of Energy and Petroleum
NAMA	National Appropriate Mitigation Action
NGOs	Non-Governmental Organizations
NIBP	National Institutional Biogas Programme
SE4ALL	Sustainable Energy for All
SGP	Small Grant Project
SMEs	Small and Medium Scale Enterprises
SNV	Netherland Development Organization
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
USD	US Dollars

Summary

The promotion of small and medium-scale enterprise (SMEs) participation in institutional biogas technology penetration has been identified as one of the five key priority energy related National Appropriate Mitigation Actions (NAMAs) in Ghana. This is in line with the country's pursuit for low carbon development options which is identified in the national climate change policy (2014) as well as the sustainable development objectives articulated in the Ghana Shared Growth Development Agenda (GSGDA).
To bring biogas as a low carbon energy source to a significant higher level in Ghana, the Sustainable Energy for All (SE4ALL) action plan intends to establish institutional biogas systems for 200 boarding schools, hospitals and prisons.

This report presents the feasibility of institutional biogas systems in Ghana and provides input for the set-up of a national biogas programme for institutional biogas.

Biogas systems are technically feasible in Ghana
At least 400 biogas systems have been built in Ghana, pre-dominantly using the fixed-dome, floating drum and Puxin technologies. The main reason to build a biogas systems is to improve the sanitation situation. Although there are several issues with existing biogas systems, many of these systems are functioning well. To ensure long term sustainability, specific attention needs to be paid to:

> *Development and enforcement of standards for biogas digesters and quality control of system design, construction and maintenance;*
> *Financial commitment from buyers / beneficiaries throughout the system lifetime, ensuring both maintenance and proper operation.*

Biogas-sanitation systems provide many social and environmental benefits
Implementing biogas systems for sanitation purposes and in addition use the produced biogas for cooking and the effluent for irrigation and fertilising creates a range of social and environmental benefits for institutions and the society as a whole. The challenges and risks that need to be addressed when implementing institutional biogas on a large scale are:

> *Education of users (use of biogas and use of the system)*
> *Ensuring no harmful pathogens are in the effluent*
> *Ensuring the biogas is used and not emitted without flaring*

Biogas systems seem economically viable
There seems to be a business case for biogas digester systems as an alternative for the currently used septic tank systems for prisons, hospitals and boarding schools. This is especially the case if a new system has to be built ("Green Field"). The payback period for such systems is less than 2 years. For institutions that wish to substitute their septic tank with a biogas system, the payback period ranges from 1-6 years for the best case scenarios.
To improve the reliability of the cost-benefit analysis, additional data gathering is needed.

The biogas private sector is ready to implement biogas

About 10 companies and organisations in Ghana have experience with the design, construction and maintenance and operation of biogas systems. At least six private companies have a good or very good knowledge base and technical experience, having built 10-100 systems each in recent years. These six have expressed their interest in cooperating / participating in a national institutional biogas programme and were present at both stakeholder workshops.

A National Institutional Biogas Programme is desirable

There is an urge felt by all relevant stakeholders in Ghana to take institutional biogas for sanitation a step forward. An interdepartmental approach targeting sanitation, renewable energy, private sector development and securing agriculture benefits is most likely to succeed. The Energy Commission is committed to lead this process in close collaboration with MoEP, MESTI, EPA and other relevant stakeholders.

Phase 1
- 20 systems implemented (2 in each region)
- Focus on learning in practice and getting good publicity
- Time frame: 1 year

Phase 2
- 50-80 systems implemented (throughout Ghana)
- Improving the systems and reducing costs
- Time frame: 1,5 years

Phase 3
- 100-130 systems implemented (throughout Ghana)
- Programme re-structured in private sector initiative
- Time frame: 1,5 years

A phased National Institutional Biogas Programme is advised, with the objectives to

> *Implement 200 biogas digester systems in public boarding schools, hospitals and prisons*

> *Kick-start the further development of a biogas market in Ghana.*

To be able to set-up and implement such a National Institutional Biogas Programme (NIBP) the following activities need to be carried out:

1. *A more detailed inventory of user needs and a cost-benefit analysis*
2. *Financial analysis and structuring of the NIBP in parallel with institutional structuring*
3. *Draft a detailed programme plan and secure funding*
4. *Secure potential funding and support for biogas from UNDP and GEF*

All the above recommendations have been confirmed by the relevant stakeholders during the stakeholder meeting of 8th October 2014, as organised by the Energy Commission.

Content

Introduction

This report describes the feasibility of institutional biogas systems in Ghana and provides input for the set-up of a national biogas programme with a focus on institutional biogas. It is a result of a study for the Energy Commission in Ghana, executed between June and October 2014 by the biogas and bioenergy policy experts Emiel Hanekamp (Partners for Innovation, Netherlands) and Julius Cudjoe Ahiekpor (Kumasi Polytechnic and CEESD, Ghana).

The study is funded by the EU Climate Support Facility (www.gcca.eu/intra-acp/climate-support-facility), an European facility offering short-term customised technical assistance and training to public and private entities from ACP member states.

Background

Biogas technology is a proven technology noted for improving sanitation, reducing greenhouse gas emissions, helping to prevent deforestation and forest degradation, producing fertilizer and providing clean decentralised energy.

In Asia, household and institutional biogas installations have gained widespread acceptance with hundreds of thousands of biogas installations being built annually. In Africa, biogas programmes have started in recent years but have not by far reached the level of success as in Asia. In Ghana, the total number of domestic and institutional biogas installations is estimated at less than 500.

The above benefits of biogas led to its selection by the Government of Ghana as a priority technology to be implemented as part of the Sustainable Energy for ALL (SE4ALL) Country action plan for Ghana, with the aim "to improve access to modern energy for productive uses".

Ghana SE4ALL action plan

The Energy Commission (EC) is a technical regulator of Ghana's electricity, natural gas and renewable energy industries, advisor to the Government on energy matters and responsible for facilitating the implementing of the SE4ALL Country Action Plan (CAP).

The specific activity formulated within the SE4ALL CAP is "*to conduct a feasibility study to establish institutional biogas systems for 200 boarding schools, hospitals and prisons*" with 2012-2015 as implementation timeline. The purpose of this activity is to bring the use of biogas as a low carbon energy source to a significant higher level in Ghana.

The 200 systems will be a start and should stimulate and accommodate further implementation of biogas for productive usage in the country, with the long-term objective to develop a self-sustaining biogas market in Ghana.

Feasibility study and implementation plan

This study is to provide the EC with expert advice on the feasibility of institutional biogas in Ghana. The main questions that will be answered in this report are:
> *Are institutional biogas systems technically feasible in Ghana?*
> *Are biogas systems economically viable for the intended end-users?*
> *Is the biogas private sector ready to implement the intended 200 biogas systems?*
> *What are the social and environmental advantages and risks of biogas systems?*
> *What policies and institutional initiatives and arrangements support or can support the implementation of institutional biogas?*

In relation to the intended 'national biogas programme' -starting with 200 institutional systems- the report addresses:
> *The relevant stakeholders for such a programme and their potential role.*
> *The market potential for institutional biogas systems in Ghana.*
> *Building blocks for such a biogas programme.*

Activities undertaken for the study

For this study the following activities have been executed:
> *desk research: an overview of the literature used is provided in Annex D;*
> *interviews with relevant stakeholders: an overview of interviews is provided in Annex A;*
> *two stakeholder workshops have been organised by the Energy Commission. The first on 27th August 2014 and the second on 8thOctober 2014; the lists of participants are in Annex B;*
> *site visits to existing institutional biogas installations and visits to institutions for a needs-assessment: an overview of visits is provided in Annex A;*
> *a cost-benefit analysis for institutions, based on financial data provided by the biogas private sector, individual boarding schools and the Ghana Prisons Service (see chapter 4).*

Guidance for the reader

This report presents the results of the study that has been carried out between June and October 2014. In chapter 1 to 8 the feasibility of institutional biogas in Ghana is assessed. Chapter 9 discusses a National Biogas Programme for institutional biogas.

The report is reviewed and approved by the Energy Commission. The conclusions and recommendations will be used by the Energy Commission to take further actions for setting-up a National Biogas Programme to realise 200 institutional biogas systems.

1. The intended biogas system

1.1 Biogas for cooking; overview of a digester system

Biogas has been selected by the Government of Ghana as a priority technology to be implemented as part of the SE4ALL CAP, with the aim “To improve access to modern energy for productive uses”.
The specific activity formulated within the SE4ALL CAP is “*to conduct a feasibility study to establish institutional biogas systems for 200 boarding schools, hospitals and prisons*”.

The intended biogas systems (biogas digester) will decompose human faecal waste into biogas which will be used for cooking purposes.

The choice for the three types of institutions is steered by the following considerations:

> *These institutions all have toilets and a, more or less, fixed number of people regularly visiting them. This means a stable amount of feedstock will be periodically fed in the biogas digester. This is important for a steady amount of biogas being produced and also has advantages in quantifying the size of the system.*

> *These institutions all have the need for energy in the form of LPG, firewood, charcoal or a combination of these three for heating or cooking purposes. Biogas can replace (part of) this energy use.*

> *The three types of institutions all have a role in the community. Potential cost savings will therefore benefit either the community or the government - as (partial) funder of these institutions - which indirectly will benefit the community as well.*

Figure 1 Schematic overview of intended biogas system

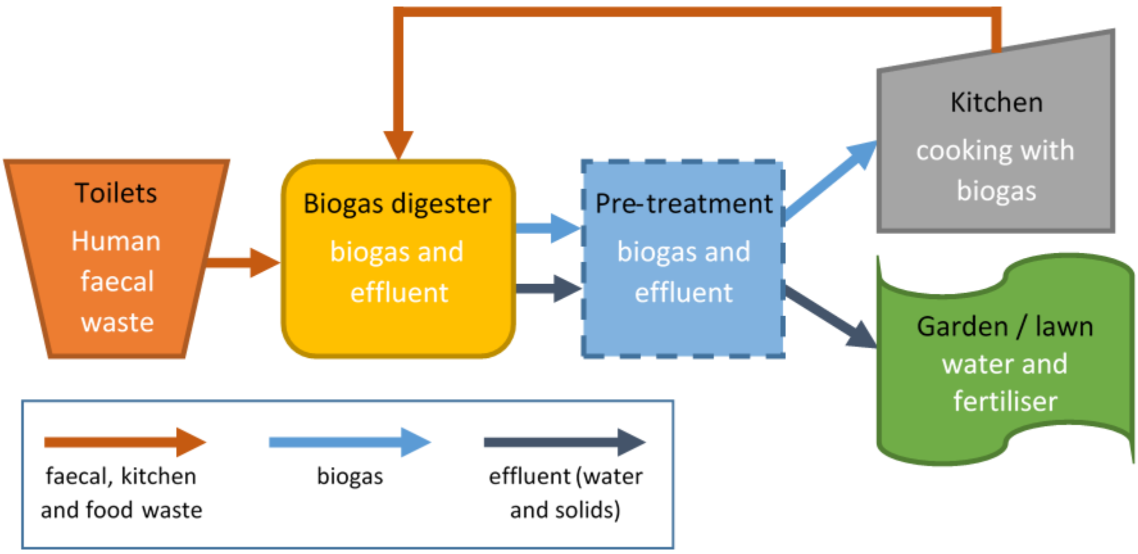


Figure 1 shows schematically the intended biogas system. In most cases the effluent needs to be pre-treated before being used for water and fertilizing purposes, to be sure the pathogens are sufficiently destroyed and the water quality meets EPA standards. The biogas needs to be dehydrated to be used in specific stoves, to prevent corrosion problems.

The retention time (the time the feedstock resides in the digester) of a biogas digester treating mainly faecal waste and with a lot of water and urine does not have to be much longer than 20 days. An oxidation tank will be needed to treat the effluent from the digester to be sure it will be free of pathogens and can be used as an organic fertiliser. The retention time and the amount of input into the digester will determine the size of the dome(s).

In addition to the faecal waste that can be used as a feedstock also other organic waste streams can be used. In the case of institutions, organic kitchen waste and food left-overs are the most relevant. When adding other organic waste streams, care has to be taken how and how much is added, but basically everything can go in the digester. Adding additional waste streams like kitchen and food waste is very interesting as the methane potential [1] of this waste is much higher than from faecal waste as shown in Table 1. An additional advantage is that this waste does not need to be disposed of anymore, which provides additional cost reductions.

Table 1 Methane potential of different waste types

Type of waste	Methane potential (m^3 CH_4 / kg)	Reference
Faecal sludge	0.14	Gallagher 2010
Kitchen refuse (food waste)	0.17 – 0.29	Lim, 2011
Maize (crop yield)	0.29 – 0.34	Weiland 2010
Food remains	0.55	Al Saedi, 2008
Poultry slaughter	0.6 – 0.7	Salminen and Ritala 2002

The intended biogas systems (can) have a number of advantages compared with currently used technologies and practices:

> *Biogas is produced, a renewable energy source, preventing CO_2 emissions but also reducing the amount of wood used for cooking.*
> *When fire wood is replaced smoke and its health effects are diminished.*
> *The digester will take care of proper decomposing of the faecal waste, destroying (almost) all potentially harmful pathogens. This also has a positive health effect.*
> *The digester effluent can be separated into a liquid part and a solid part. The liquid effluent can be used for irrigation of gardens, lawns and food crops and the solid effluent can be used as fertiliser.*

The above advantages have been shown to be valid - also in the Ghanaian context - by several studies, the majority done by respectable local research institutes.

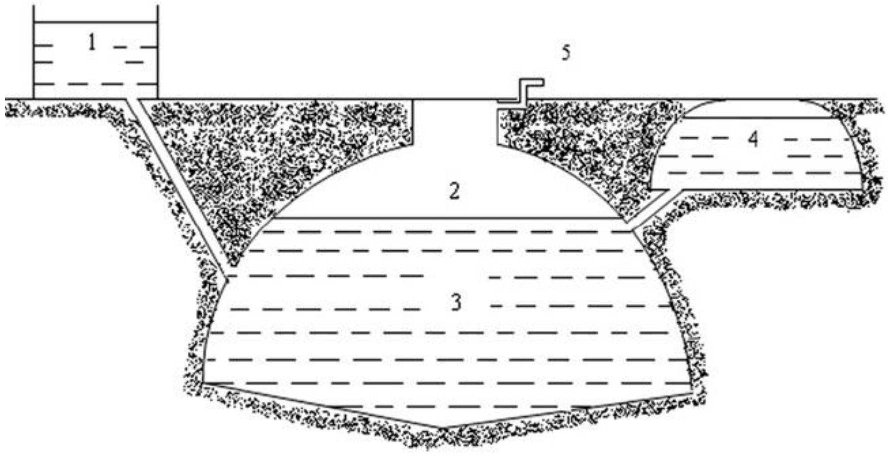
[1] The methane potential of organic material is the potential methane yield from anaerobic digestion.

1.2 Biogas technologies used in Ghana

The three main types of biogas technologies that have been designed, tested and disseminated in Ghana are the fixed-domed, floating drum and Puxin digester [35]. The three do not differ very much as they all require construction of a digester made of concrete and or bricks. The Puxin digester uses moulds to build the digester and uses some prefabricated parts.

A fixed dome[2] plant comprises of a closed, dome-shaped digester with an immovable, rigid gasholder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensation tank as shown in Figure 2. Gas pressure increases with the volume of gas stored in the gasholder. If there is little gas in the gasholder, the gas pressure is low. When gas production starts, the slurry is displaced into the compensation tank.

Figure 2 Schematic picture of a fixed dome digester

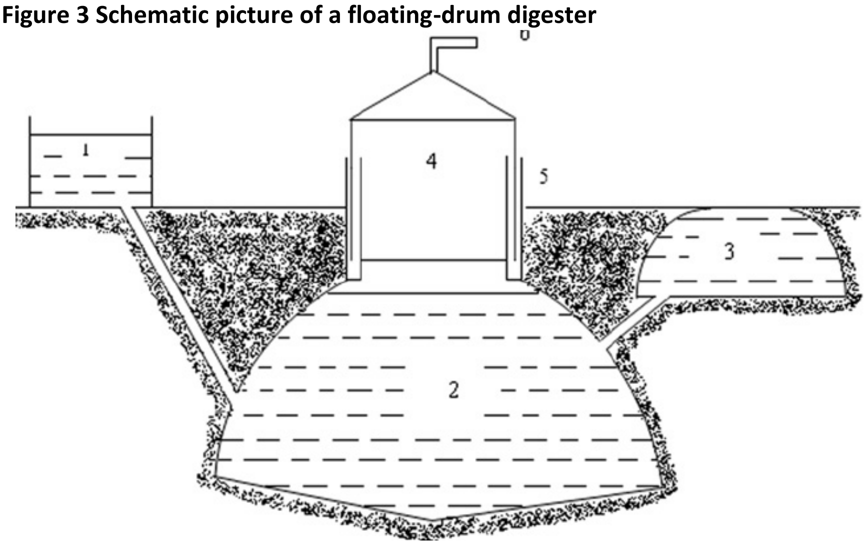


1. Mixing tank with inlet pipe. 2. Gasholder. 3. Digester. 4. Compensation tank. 5. Gas pipe.

Floating-drum[3] plants consist of an underground digester and a moving gasholder as shown in **Fout! Verwijzingsbron niet gevonden.** The gasholder floats either directly on the fermentation lurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content [12].

[2] The fixed dome digester is a Chinese technology.
[3] Floating drum digester is an Indian Technology.

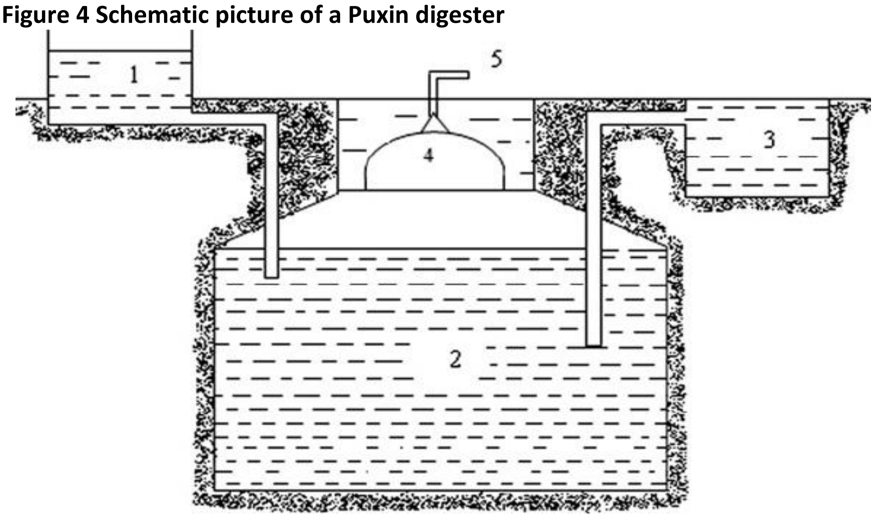
Figure 3 Schematic picture of a floating-drum digester



1. Mixing tank with inlet pipe. 2. Digester. 3. Compensation tank. 4. Gasholder. 5. Water jacket. 6. Gas pipe.

The Puxin biogas[4] digester is a hydraulic pressure biogas digester, composed of a fermentation tank built with concrete, a gasholder made with glass fibre reinforced plastic and a digester outlet cover made with glass fibre reinforced plastic or concrete. The gasholder is installed within the digester neck, fixed by a component; the gasholder and digester are sealed up with water [2] as shown in Figure 4.
The mesophilic[5] temperature range for biogas production is 20-40 °C [5] and with Ghana annual temperature of 25 °C, this implies that most biogas plants in Ghana operate well within mesophilic temperature conditions.

Figure 4 Schematic picture of a Puxin digester



[4] Puxin digester is a Chinese Technology.
[5] A mesophile is an organism that grows best in moderate temperature, typically between 20 and 45 °C

1. Mixing tank with inlet pipe. 2. Digester. 3. Compensation tank. 4. Gasholder. 5. Gas pipe.

1.3 Other existing technologies for institutional biogas digesting

For this study the researchers have only looked at the three technologies mentioned in the previous paragraphs. We are aware of many more interesting digester technologies, especially the prefabricated ones[6], bag digesters[7] and more advanced technologies, for example the Continues Stirred Tank Reactor. The first two technologies can be made of cheap materials like plastics or composite materials but these technologies are mainly targeting the domestic market and it is unclear if they also can be used for the institutions that are targeted. This study did not research if the prefabricated ones could also be used for example when connected in series. The latter technology is not common in Ghana.

1.4 Conclusions

Because the aim of the Ghana government is to implement 200 institutional systems in a short time span, we focussed on those technologies that have proven to be working in Ghana and for which a sufficient number of private companies can provide the technology and knowledge (e.g. the fixed dome, floating-drum and Puxin digester technologies). In time the appropriateness and economic viability of other technologies should be researched.

[6] African examples of existing technologies are SimGas (Tanzania) and Agama (South-Africa)

[7] For example Flexi Biogas (Kenya)

2. Technical feasibility of institutional biogas in Ghana

2.1 Biogas digesters in Africa

In Ghana, the total number of domestic and institutional biogas installations in 2010 was estimated at some 250 [28]. Based on the interviews (Annex A) with private biogas companies the current number of constructed biogas systems is estimated to be at least 400.
In Asia, household and institutional biogas installations have gained widespread acceptance with millions of installations being built annually. The success is a result of successful national biogas programmes. Sister nations such as Kenya and Tanzania, already in 2007, had over 2,000[8] and 5,000[9] plants constructed respectively. However these are mainly domestic biogas systems.

Recently also in Africa, biogas programmes have started being successful. The Africa Biogas Partnership Programme (ABPP)[10] reports that in 2012 in Burkina Faso, Ethiopia, Kenya, Senegal, Tanzania and Uganda a total of 27,275 digesters have been built resulting in amongst others: a growing number of biogas construction enterprises, reduced building costs, increased bio-slurry use, increased integration of the technology in agricultural systems, 136,375 people (women and children) are being protected from indoor air pollution, 256 kt reduction of GHG emissions annually and the substitution of 263 kt of biomass and nearly 2,000 litres of fossil fuel (kerosene and LPG). These biogas programmes are also focussed on domestic (in rural areas) biogas.

2.2 Biogas digester systems in Ghana; lessons learned

Sanitation systems or biogas systems?
The vast majority of the systems in Ghana have been built or are being used for sanitation purposes only. The produced biogas is usually released into the air without flaring (burning), see Figure 5.

This situation is not entirely unexpected. Due to negative experiences in the past with biogas systems, e.g. the Appolonia Electrification project in 1992 [3], the market interest for biogas for productive use was almost non-existent. These negative experiences also resulted in a low involvement and commitment by government. Following the low market interest for biogas as an energy source, private biogas companies have marketed the technology in recent years on purely business grounds. The focus of biogas technology shifted from provision of energy (use of biogas) 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 or proper handling of the biogas produced.

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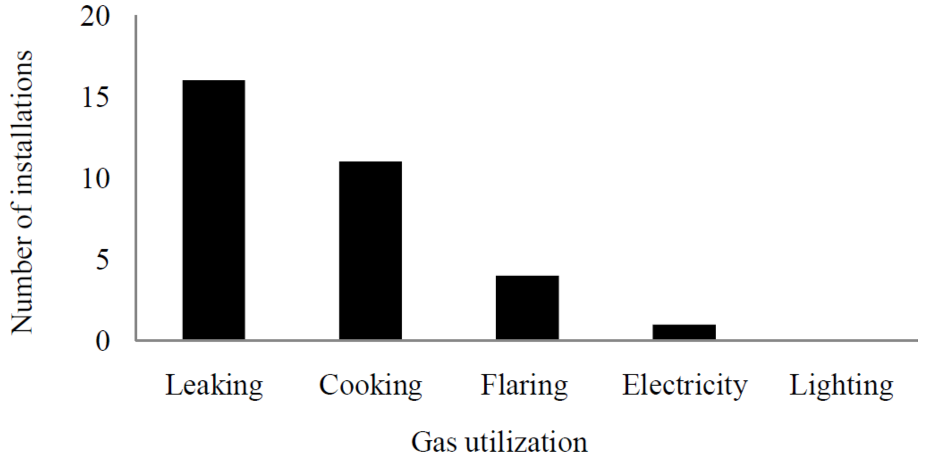
[8] Marree F., Nijboer M., Kellner C. Report on the feasibility study for a biogas support programme in the northern zones of Tanzania. SNV publication, Nairobi, Kenya, 2007.
[9] Erosion, Technology and Concentration (ETC) Group. Promoting biogas systems in Kenya: a feasibility study in support of Biogas for Better Life – an African initiative. Commissioned by Shell Foundation. Nairobi, Kenya, 2007.
[10] ABPP website: http://africabiogas.org/

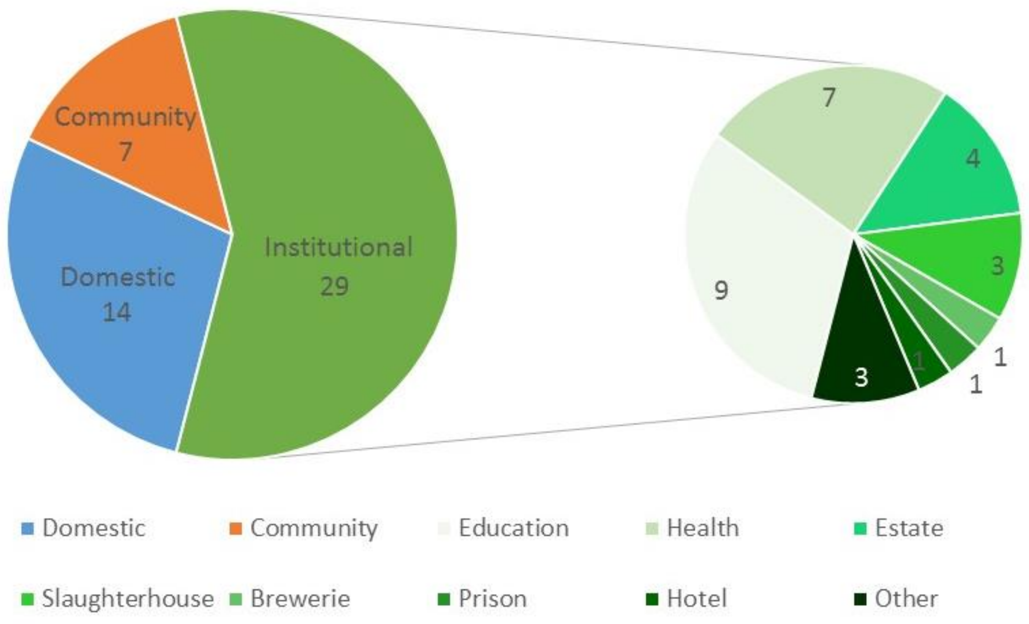
Figure 5 Biogas usage (based on the number of surveyed plants, functioning fully or partially [3]



Many systems are not working properly or not at all

Several studies [2, 3] have shown a huge portion of the biogas systems that have been built are not working properly or are not working at all.

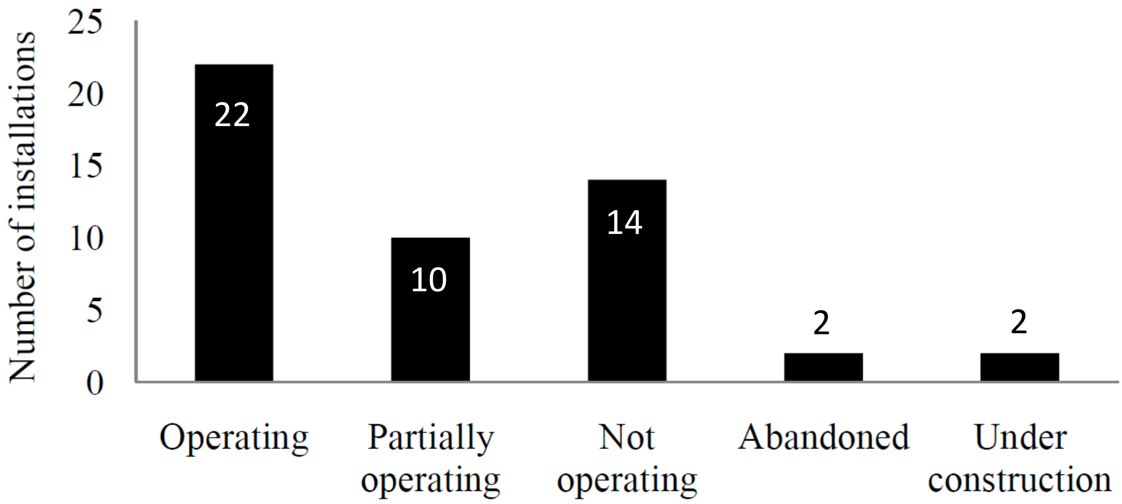
Figure 6 Surveyed 50 installations grouped into institutional, community, and domestic plants [3]



Between June 2008 and February 2009 researchers from KNUST and Kumasi Polytechnic conducted an assessment [3] of 50 biogas plants, in order to ascertain the true state of biogas technology in Ghana. The sample size (50 plants) was determined from the population (100 known biogas plants) as captured in a survey by KITE [35] using stratified and convenience sampling techniques.

Out 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 included 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 bio latrines.

Figure 7 Functional status of the 50 surveyed installations [3]



The survey also revealed that the majority of plants (76%) had been constructed mainly in the cities for the treatment of human excrement from flushing toilets.

Lack of technical expertise of private biogas construction companies

About 20 Ghanaian private companies and research institutes have been active in building biogas digesters and sanitation systems able to produce biogas (see also chapter 5). A few are purely focussed on biogas or sanitation but most of them also have other business areas they are actively involved in. The latter is due to the slow market for biogas digesters.

Besides the organisations regularly building brick biogas domes it has been noticed that a number of systems have been built by individual masons. Although these may be good masons, they usually do not have the required knowledge and skills to build a biogas dome. This has resulted in poorly functioning, or failed systems.

Although quite a few systems that have been built in the past do not function properly, a lot of systems do seem to work fine and customers are satisfied.

In the course of this assignment (and other assignments), the researchers have visited 12-15 functioning and non-functioning biogas systems and were able to talk with users as well. We also had detailed technical and non-technical discussions with 7 biogas construction companies. These companies belong to the 10 companies in Ghana having installed the highest numbers of biogas systems (10-50 each). Based on these discussions and the site visits, where we have seen some of their work, we anticipate the knowledge and expertise of these experienced companies ranges from good to very good.

System size is not fit for its purpose

A very common problem with biogas digesters is the under sizing of the biogas system (especially the dome). Sometimes this is a result of 'improper' design of the system due to lack of knowledge. More often the private sector tends to size the biogas digester dome as small as possible to make the system as cheap as possible for the client. The digester makes up more than 50 % of the total cost of the biogas system.

Another reason why biogas digester systems are not properly sized is that after commissioning, the number of users is increased or more toilets are connected to the system, e.g. schools expanding their number of students and building new dormitories with additional washrooms. In most cases this is caused by ignorance of the user.

As a result of the under sizing, the digester can have several problems:

> *Bad odour;*
> *Not producing sufficient biogas;*
> *Effluent with high pathogen levels (not meeting EPA standards).*

Usage of low quality materials and bad construction

In a few cases the use of low quality building materials or bad construction is the reason for biogas systems to collapse. In these cases the private company or mason did not have sufficient knowledge and experience with building biogas digesters. The construction of a digester dome requires specific knowledge and skills from masons and also the usage of good quality materials (e.g. bricks and mortar). When the dome is not constructed perfectly, the digester will not function properly and using low quality building materials can cause leakage and break down of the system after a few years of operation. When using high quality materials a digester will have a lifespan of 15-20 years.

Lack of maintenance

Lack of maintenance is one of the major problems causing systems to fail after a few years of operation. A biogas digester does not require a lot of maintenance but sometimes some minor technical repairs are needed for instance, repairing small cracks in the dome, taking care of gas leakages (gas connections) and, replacing the gas balloon. In practice, users do not make arrangements with the biogas company to take care of such maintenance after commissioning. Quite a few users have expressed to us they do not know the company that has constructed the system. Also when some maintenance has to be done, they do not know whom to contact. As a result many digesters are not functioning properly or not at all. However with some minor repairs (which can usually be done at low costs), many of these systems can operate fully.

Another type of necessary maintenance is caused by improper usage of the system. This is explained in the following paragraph.

Improper usage
When non-biodegradable items are put in the system (often flushed), this does not only have a negative impact on the performance of the biogas system (production of biogas) but also can cause blockages, both in the inlet of the digester and the digester itself. These blockages need to be removed. Newly designed systems have simple but effective technical measures (e.g. sieves) to prevent non-biodegradable items to enter into the digester and also easing the cleaning of the inlet.
Another type of improper usage is when 'feeding' the digester with biodegradable material that is not properly pre-treated or has a negative impact on the microorganisms (bacteria) that take care of the breakdown of the biodegradable material in the biogas digester. In a worst case scenario 'bad feeding' can cause the bacteria culture in the system to perish fully. 'Starting-up' the system again can take a few months.
The above problems are caused by ignorance and inexperience of users caused by inadequate or missing instructions on how to use the system.

2.3 Conclusions

Biogas systems are technically feasible in Ghana. At least 400 systems have been built, many of them functioning well. In countries in Africa and Asia, similar to Ghana, hundreds of thousands of digester systems (based on the fixed dome technology or similar technologies) have been built and are also functioning well.

The anticipated problems, with systems that have been built in Ghana in recent years, can be overcome when properly addressed in a biogas programme. Issues to take care of are:
> *Development and enforcement of standards for biogas digesters and quality control of system design, construction and maintenance;*
> *Financial commitment from buyers / beneficiaries throughout the system lifetime, ensuring both maintenance and proper operation.*

These measures should secure long term sustainability of the biogas digester systems.

The majority of biogas (biogas-sanitation) systems that have been built in Ghana are waste treatment facilities, meant to improve the sanitation situation and lower sanitation costs. This has been the driving force for the biogas market in recent years.

3. Social and environmental benefits, risks and challenges

In recent years institutional biogas systems have been mainly built as waste treatment facilities for toilets. Institutions that opted for biogas digester technology instead of the commonly used sanitation systems as the (Kumasi) Ventilated Improved Pit (KVIP) and toilets with septic tanks, wanted to solve their practical challenges with odour and desludging of these systems. In addition the institutions saved the costs associated with desludging of the septic tanks. The produced biogas is seldom being used but instead usually just released into the air without flaring (burning), with a severe impact on the CO_2 emissions of the installation (see paragraph 3.4). The use of biogas systems for sanitation partly has been stimulated by EPA as new institutional structures are obliged to use anaerobic digesters as standard technology.

This chapter describes the social and environmental benefits both for the institutions and the society as a whole, but also the social and environmental risks and the challenges when implementing institutional biogas.

Valley View University - Biogas Plant for Waste Water Treatment and Renewable Energy

The biogas plant on campus was completed in January 2005. Its location is next to the new cafeteria and the sanitary block, which are the main "waste" providers and biogas users. Since the decentralized sanitary concept suggests a separation of different flow streams of waste water such as urine, grey and black water, the process was optimized which has led to a reduced size of the biogas digester.

Biogas plant

sludge digester

The simple and robust dome system is a continuous flow plant. Black water of the sanitary facilities is treated anaerobically in the biogas digester together with organic waste from kitchen and farms. The produced biogas is collected in a PE sack and used for cooking in the cafeteria. The sludge on the ground of the digester can be used as fertilizer in agricultural areas of the campus.

The outflow of the digesters discharge into three expansion chambers. From there the treated waste water goes into a septic tank where the wastewater is treated again. From the last filtration chamber purified water is pumped into an elevated tank and used under gravity for irrigation and as fertilizer on the farmland. The main purpose of the digesters is the treatment of black water. The production of biogas is just a secondary benefit.

Text block 1: Example of a success story of institutional biogas at Valley View University

In addition to the benefits mentioned above there are many more, both for the institutions and the society as a whole. This is especially the case if all three advantages of biogas systems are used to their full potential:

1. *Improve sanitation*
2. *Use the biogas as an energy source*
3. *Use the effluent for irrigation and as an organic fertiliser*

Many studies on biogas in Ghana have shown these potential advantages. References [1], [11], [12] and [14] are only a few of them.

African Regent Hotel - Biogas Plant for sanitation and biogas for cooking

The biogas plant at the hotel premises was completed in January 2005. It is located next to the new cafeteria and the sanitary block, which are the main "feedstock" providers and biogas users. The decentralized sanitary concept suggests a separation of different flow streams such as urine, grey and black water, which has led to a reduced size of the biogas digester.

Biogas storage balloon in the corner of the car park

The simple and robust dome system is a continuous flow plant. Black water of the sanitary facilities is treated anaerobically in the biogas digester together with organic waste from kitchen and farms. The produced biogas is collected in a PE sack and used for cooking in the cafeteria. The sludge on the ground of the digester can be used as fertilizer in agricultural areas of the campus.

The out-flow of the digesters discharge into three expansion chambers. From there the treated waste water goes into septic tank where the wastewater is treated again. From the last filtration chamber purified water is pumped into an elevated tank and used under gravity for irrigation and as fertilizer on the farmland. The main purpose of the digesters is the treatment of black water. The production of biogas is just a secondary benefit.

Text block 2: Example of a successful biogas plant at the African Regent Hotel in Accra

3.1 Socio-economic benefits of institutional biogas

Based on the literature studied it is evident institutional biogas has a wealth of socio-economic benefits. The following tables present an overview of these benefits.

Figure 8 Socio-economic benefits of institutional biogas

Benefits for institutions
Reduced / no odour
No desludging (and related costs) needed
Reduced nuisance from smoke and smoke borne diseases when substituting fire wood with biogas
Less water use (and costs) when using (watery) digester effluent for irrigation
Improved crop yield when using digester effluent as organic fertilizer (or cost reduction when replacing artificial fertilizer or income generation when selling fertilizer)
Cooking with biogas is easier than with firewood (or charcoal), saves time and is clean (no soot)
Savings in institution's health related expenditures
Health related productivity (reduction in unproductive time due to sickness)
Societal benefits
Improved fertilizer availability which positively impacts cropland productivity and food security
Reduction in smoke borne diseases and infant mortality rates
Reduction of diseases caused by pathogens in human excreta (e.g. gastrointestinal diseases and cholera)
Health related productivity (reduction in unproductive time due to sickness)
Savings in health and illness related costs
Increased private sector development
Employment generation: skilled (e.g. masons, plumbers) and unskilled
Increased research activities and associated employment (e.g. civil engineers, agronomists)

The most important driver for the implementation of institutional biogas is (and has been in recent years) the improvement of the sanitation situation [14]. The commonly used sanitation systems such as the (Kumasi) Ventilated Improved Pit (KVIP) latrine and toilets with septic tanks have many problems. Also open defecation is still widely practised. Of course these problems are partly caused by the improper disposal of the faecal waste that is collected from these systems. The 12 institutions visited by the researchers all have toilets with septic tanks.

The recent outbreaks of cholera in Ghana have raised the emphasis on using improved sanitation technologies based on anaerobic digestion. Well-functioning anaerobic digesters produce an effluent (sludge consisting of water and solids with nutrients comparable with fertilizers) that is entirely free of harmful pathogens. When disposing the effluent into the environment or using it for irrigation and / or as a fertilizer, it will not have any health risks.

Another potential advantage of wide-scale implementation of digesters, instead of septic tanks, is the use of the produced biogas as an alternative for firewood or charcoal. When using

firewood a lot of smoke is produced, with all kinds of irritations to the eyes, nose and lungs and eventually causing health problems. The institutions visited by the researchers primarily use firewood for cooking with some using both LPG and firewood.
According to the World Health Organization, 1.6 million people die annually from indoor air pollution caused from cooking, this is more than the fatality figure from malaria. The level of small particles in the air in a house with open fire is 3060 μg/m^3. The EU maximum level of small particles in the air is 40 μg/m^3.[11] In Ghana, about 13,400 of deaths recorded annually are estimated to be related to cookstoves and fuels used. [12]

Figure 9 Photo's on indoor air pollution

Left: Poster from the Ghana Alliance for Clean Cookstoves, fighting indoor air pollution [photo: Emiel Hanekamp, Kumasi Anglican High School, 2014] Right: Woman cooking on an open fire [photo: practicalaction.org]

A side effect of stimulating the implementation of institutional biogas is the development of a biogas private sector in Ghana, with the creation of jobs in this sector as a result. Compared with installing septic tanks, biogas digesters are more labour intensive (one of the reasons why they are more expensive). Also the design, construction and maintenance of biogas digesters require more skilled labourers, for example masons and gasfitters, compared with sceptic tanks. Also for maintaining and operating the biogas digester some skilled labourers are needed.

On a societal level illnesses like cholera, dysentery and other gastrointestinal diseases related to unhygienic situations will less often occur having a positive impact on the number of people getting ill annually. This will have a positive impact on the sickness absenteeism levels and other health and medical treatment related costs.

3.2 Environmental benefits associated with institutional biogas

There are a number of potential environmental advantages using anaerobic digesters. The biogas can be used as a substitute for (part of) currently used cooking fuels. For institutions this seems to be mainly firewood, with LPG and charcoal as additional energy sources. Substituting

[11] https://hivos.org/biogas/
[12] Global Alliance for Clean Cookstoves, http://www.cleancookstoves.org/countries/africa/ghana.html

wood and charcoal will have direct positive impacts on deforestation and reduced CO_2-emissions.

Figure 10 Environmental benefits of institutional biogas

Environmental benefits
Decreased water use
Increased usage of organic fertilizer, decreased use of artificial fertilizer
Increased use of a renewable energy source, resulting in lower carbon dioxide emissions
Reduced deforestation and desertification as biogas is used instead of firewood
Improved soil fertility

Also the effluent (bio-slurry) of the digester can be used for irrigation and as an organic fertilizer for lawns and flower and vegetable gardens, thereby reducing the amount of fresh water being used (sometimes also a cost saving) and increasing yields or reducing costs for fertilizers.

Text block 3: Impacts of using the effluent (the bio-slurry) of a biogas digester

Bio-slurry, an end product in a biogas digester is used in agriculture as organic fertilizer and in fish farming as fish feed. Bio-slurry use leads to improved agricultural produce, hence improved nutrition and food security. 72% of the surveyed biogas owners in Uganda reported that slurry has effectively fertilized their gardens. **84% reported improved farm productivity and income**. Most, 54 % applied it in its liquid form. Composting could further enhance the quality of the slurry but is not yet widely practiced. The majority of the respondents said they used this slurry in their own gardens as compared to only 9 % who said that they sold it for money. Selling bio-slurry is however an interesting business potential for farmers and deserves more attention from the programmes.
Source: website Africa Biogas Partnership Programme (ABPP); http://africabiogas.org/

3.3 Social-cultural challenges when implementing institutional biogas

Some of the literature studied (see for example the feasibility Study for a National Domestic Biogas Programme in Burkina Faso [34], page 75), discusses the potential issues when using biogas and the effluent (water and fertilizer) as it is produced using human faecal waste. This has also been mentioned by a few people the researchers have been in contact with. Apparently there's a social perception that cooking from biogas is "unclean" or "dirty" because it is produced using faecal matter. The magnitude of this issue has not been researched but does not seem to be a real threat for the successful implementation of biogas systems and the full use of its 'products'. Proper education can probably change the perception.

There are a number of installations in Ghana where the biogas is primarily being used for cooking. Good examples are: The African Regent Hotel, Valley View University and the Kumasi Institute of Tropical Agriculture (KITA). The University and college also use the effluent.

Throughout Asia and in other African countries[13] this social barrier does not seem to be of great importance and might even be further diminished when providing stakeholders and users with factual information and showing them the advantages of using biogas.

Another issue is the flushing of non-biodegradable items like sanitary towels and other non-biodegradable waste. These will either stay inside the digester, reducing the capacity of the system, or will ‘contaminate’ the effluent. Also they can cause blockages both in the inlet of the system and the dome itself, which increases the need for maintenance and increase maintenance costs. This issue can be managed by informing toilet users and taking some technical measures, preventing large non-biodegradable items to enter into the digester system.

A third issue is the use of the biogas. Currently the digesters are used for solving sanitation problems while the biogas is seldom used. Most institutes and the relevant people involved, are not aware what biogas is, how they can use it and what its potential risks are. As a consequence of this unintentional ignorance biogas is not commonly used and properly handled but released into the air without flaring (burning). This results in a negative environmental impact (see next paragraph) and a safety risk, as biogas contains 50-75% methane that will form a highly explosive gas as it is mixed with oxygen.

3.4 Environmental and health risks associated with institutional biogas

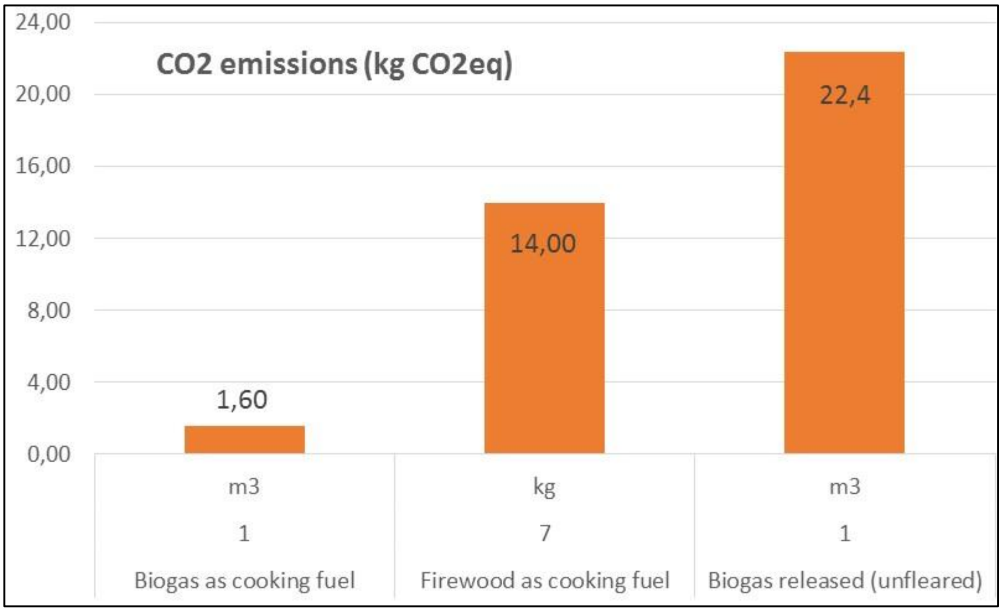
Biogas systems have many intrinsic social, economic and environmental advantages but there are also some risks.

A major risk, which unfortunately can be seen with many biogas systems in Ghana, is that the effluent from the system still contains potentially harmful pathogens; pathogens that originate from the faecal waste. This occurs when the faecal waste is not being treated long enough in the digester. This is a result of the digester size being insufficient for the amount of feedstock to be treated. There can be many reasons for this: improper system design, bad operation or incorrect feeding of the digester. As a consequence the amount of biogas produced is also less than what could be produced but more importantly the effluent is probably not pathogen free and the water that is being discharged will not meet EPA standards. When the effluent is being discharged into the environment or is used for irrigation purposes or as a fertilizer, people can get ill from the pathogens still active in the effluent.

Another environmental risk is the unnecessary emission of methane. Most digester systems in Ghana do not use the produced biogas and release it in the air without flaring. Biogas consists of 50-75% methane. With a comparative impact of methane (CH_4) on climate change being over 20 times higher than CO_2, over a 100-year period, not burning the biogas is much worse.
This can be seen from the following graph.

[13] The Africa Biogas Partnership Programme (ABPP) has constructed in 2012 and 2013 almost 16.000 domestic biogas systems in five African countries; Ethiopia, Kenya, Tanzania, Uganda, and Burkina Faso.

Figure 11 Comparing the CO_2-emissions for three situations; 1) when using the biogas from the digester, 2) when using an equivalent amount of firewood 3) when biogas is released in the air.



Both risks can be mitigated or entirely resolved using the following mix of measures:
> *Awareness and information campaigns;*
> *Setting-up standards for design, construction and operation of biogas systems and control mechanisms to check these standards;*
> *Regulatory measures and enforcement.*

3.5 Conclusions

Implementing biogas systems for sanitation purposes and in addition use the produced biogas for cooking (or other energy purposes) and the effluent for irrigation and fertilising creates a range of social and environmental benefits for institutions and the society as a whole. Institutions able to use all three benefits (e.g. agricultural boarding schools) are favourable for selection as pilot facilities. As there is no practical evidence available in Ghana about the social and economic benefits of using the biogas and the effluent, it is advised to include a monitoring system able to quantify these benefits, when a pilot phase is implemented.
There are also some issues and risks that have to be addressed when implementing institutional biogas on a large scale:
> *Education of users (use of biogas and use of the system)*
> *Ensuring good maintenance and operation practices*
> *Ensuring no harmful pathogens are in the effluent*
> *Ensuring the biogas is used and not emitted without flaring*

These risks can be mitigated or reduced when properly addressed in a National Programme. Other biogas programmes in Asia and Africa have proven that this is feasible.

4. Cost-benefit analysis of institutional biogas systems in Ghana

Part of this feasibility study is focussed on the costs and benefits of biogas systems for the beneficiaries (boarding schools, prisons and hospitals). The initial plan was to conduct this analysis based on desk research. However at the first stakeholder meeting, 27th August in Accra, the participants asked the researchers to make their own inventory of costs and benefits of institutional biogas systems. This was done between 28th August and end of September 2014.

The aim of the cost-benefit analysis is to answer the following questions:
> *Is there a viable business case for institutions to install biogas systems instead of the currently used septic tanks? If not,*
> *What is the amount of the additional funding (or funding mechanism) needed to make biogas an interesting alternative for institutions?*

4.1 Methodologies and approach used

When executing the cost-benefit analysis, the researchers used the following approach:
1. *Collect data from institutions on type of sanitation technology used, number of people using washrooms, cooking fuels used, sanitation costs and fuel costs.*
2. *Collect quotations from the biogas private sector for three standard systems/situations.*
3. *Estimate the costs for septic tanks for the three standard situations.*
4. *Calculations (based on standard figures) of the system size for the three standard situations and the amount of biogas produced.*
5. *Combining the above figures to calculate the payback time (based on a Discounted Cash-Flow-Analysis).*

The researchers visited from 17-29 August several schools, hospitals and prisons. In addition Ghana Prisons Service and Ghana Health Service where contacted to provide the data and information as described above.
In total, 7 private biogas companies have been contacted to provide quotations for the following standard biogas systems / situations, with a very brief textual description (see text block below):
1. BIOGAS SYSTEM 1: Boarding school with 800 students (1,000 in 2020)
2. BIOGAS SYSTEM 2: Boarding school with 3,500 students (4,000 in 2020)
3. BIOGAS SYSTEM 3: Prison with 4,000 inmates (4,000 in 2020)

Text block 4: brief description of the anticipated standard biogas system / situation

The systems include: new toilet facilities (not the building), a biogas digester, an oxidation tank, a water purification facility and all necessary facilities (piping, gas storage, etc.) for the biogas to be used for cooking in the kitchen. All three situations currently use 9 litre flush WC's.

Based on publically available data estimations have been made of costs for sceptic tanks as an alternative for a biogas systems.

Using conservative but generally used data (see next paragraph), the system size has been calculated. Also very conservative data has been used when calculating the amount of biogas produced (see next paragraph).
For the feedstock of the biogas system both human faecal waste and a limited amount of kitchen waste (kitchen leftovers and food leftovers) has been taken into account.
As interest and inflation rates in Ghana are high, a simple pay-back time calculation is very inaccurate, therefore a discounted cash-flow analysis has been used and payback times have been calculated using 0%, 15% and 25% discounting rates.

4.2 Limitations and assumptions

Limitations of the used methodology
Biogas systems can provide a number of benefits for both the beneficiaries (institutions) and the society at large. Some examples of these benefits are:

> *Institutions: solving poor sanitation situations, costs savings on desludging of septic tanks, costs savings on cooking fuels, providing water and organic fertilizer for gardens and lawns and less smoke in kitchens.*

> *Society: reducing health related risks and costs due to better treatment of human faecal waste and replacement of wood based cooking fuels.*

In chapter 3 the social and environmental benefits, challenges and risks have been discussed. In paragraph 4.6 the potential economic benefits are elaborated in more detail.

For this cost-benefit analysis only the cost savings related to the replacement of currently used wood fuels and the cost savings related to the desludging of septic tanks is taken into account. These are the direct costs for institutions that are easy to determine. The other costs and cost savings are much more difficult to quantify (e.g. higher yields due to use of organic fertilizer, costs as a result of smoke related diseases of employees).
The societal costs are not taken into account all together as they are out of the focus of this research. The overall (economic) benefits of institutional biogas systems are clearly much higher than calculated in this report.

Limitations of the data gathered
Due to a number of practical reasons, the researchers were able to collect relevant data only from a limited number of institutions. Usable information could be collected from five prisons (via the Ghana Prisons Service) and two schools (based on 12 field visits of the researchers). Unfortunately no data from hospitals could be gathered during the time frame of the assignment, despite three field visits to hospitals and several contacts with the Ghana Health Service.
The researchers have not been able to verify the data that was provided. Assessing the actual numbers, large variations can be seen (see paragraph 4.4).

Four of the seven private biogas companies provided quotations for the three standard systems. These quotations vary a lot in detail and total amount (see paragraph 4.3).

Assumptions

The researchers assumed the data provided by all stakeholders to be correct and did not verify any figures. All data from institutions and the quotations from the private sector have been normalised to represent one of the three standard biogas systems. This normalisation was done based on the number of students/inmates, respectively the system size (m3). It was assumed that this normalisation can be done without creating too much of an error in the figures.

A number of basic calculations were necessary to be able to make the cost-benefit analysis:

1. *System sizes for the three standard systems /situations;*
2. *Amount of biogas produced annually;*
3. *Amount of wood fuel replaced.*

For the above calculations, the following data was used (based on publically available reports). As the variations in this type of data often is large, conservative numbers, e.g. numbers that in the end will give a conservative financial benefit, have been used.
The following tables provide the numbers that have been used for the above calculations.

Table 2: Numbers used calculating the system size

Variables (unit)	Number
Retention time (days)	20
Frequency of using toilet (per person per day)	2
Volume of WC cistern (litres)	4.5
Faecal waste generated per person per day (kg)	0.5
Kitchen/food waste generated per person per day (kg)	0.2

Table 3: Numbers used for calculating the amount of biogas produced and wood fuel replaced

Variables (unit)	Prisons	Schools
Percentage of people using washroom per day	90%	60%
Active days per year	365	280
Frequency of use of washroom per day	1.5	1
Specific gas production from faecal waste (L/kg)	40	40
Specific gas production from kitchen waste (L/kg)	110	110
Faecal waste generated per person per day (kg)	0.3	0.4
Kitchen/food waste generated per person per day (kg)	0.05	0.1
Per capita consumption of firewood per day (kg)	0.69	0.69
Biogas-firewood replacement ratio (kg fuel/m^3)	7	7
Percentage of firewood replaced by biogas generated	22%	43%

The two tables show different numbers for the same variables (e.g. faecal and kitchen waste generated). This shows our conservative approach; not wanting to calculate a digester size that is too small and not wanting to overestimate the amount of biogas produced.

4.3 Investment, exploitation and maintenance costs for institutional sanitation systems

Biogas digester sanitation systems
In total, four well-established biogas contractors (entrepreneurs) provided cost estimations for the three biogas systems / situations. These entrepreneurs have all built between 10-100 biogas systems in Ghana. The four quotations also specified the anticipated system size. All quotations have been normalised to the system sizes for the three standard systems / situations. The system seizes are 830 m^3, for the large systems (4,000 people) and 250 m^3 for the small system (1,000 people).
The following two tables show the anonymous (normalised) quotations from the entrepreneurs.

Table 4: Normalised Biogas System costs for institutions with 4,000 people (Schools and Prisons)

Quotations large systems	Q1	Q2	Q3	Q4	Average
Cost Estimate (GHC)	523,852	346,667	1,063,689	1,075,822	752,507

Table 5: Normalised Biogas System costs for institutions with 1,000 people (Schools and Prisons)

Quotations small system	Q5	Q6	Q7	Q8	Average
Cost Estimate (GHC)	179,385	97,167	315,286	244,860	209,174

Lowest cost quotation	Highest cost quotation	Average cost quotation

As can be seen from the tables above, the system costs vary widely, between 130 - 420 US$ [14] per m^3 biogas digester. This is more or less similar to the prices indicated in the 2008 KITE report [35] and the report "*Status and prospects for household biogas plants in Ghana – lessons, barriers, potential and way forward, Cudjoe et al*" [28]. In these two reports the prices for domestic (6-10 m^3) fixed-dome biogas digesters range from 200 - 447 US$ and 235 - 446 US$ per m^3, respectively. Of course institutional digesters are much larger and one should expect economies of scale. On the other hand, the prices for materials have increased significantly in recent years and with materials being 50-75% of the total cost of a digester dome this will have a significant impact.

The prices for similar (household) systems in other countries do vary a lot: US$ 574 in Kenya, US$ 960 in Uganda, US$ 417 in Nepal and US$ 245 in Vietnam per m^3 (ETC Group, 2007). The comparative high prices in Africa seem to be a result of too limited competition in the digester market [15]; "*Higher capital cost is experienced in African biogas industry. This is due to the fact that the current market for biogas in Africa is slow. Contractors therefore tend to lump all of their costs into the unit they are constructing because they may not get another order for months (Biogas for better life, 2007).*"

The wide variation in the cost quotations can partly be attributed to the very general description of the systems / situations and the different ways entrepreneurs have interpreted them. The overall system costs are very much dependant on the actual situation (e.g. location of the

[14] Exchange rate: 1 GHC = 0.310549 USD

digester in relation to the latrines and the kitchen, the compactness of the soil and undersoil). Some of the entrepreneurs provided quotations not taking into account all these variables and presented us the minimum costs, others included costs to cover for the unexpected situations. Also some entrepreneurs are probably more expensive than others.

None of the quotations covered exploitation and maintenance costs. As exploitation and maintenance have been identified as crucial elements for the sustainability of biogas digesters, we have included exploitation and maintenance costs in our cost-benefit analysis. We have used a fixed percentage of 5% from the average system costs, starting after three years of operation.

Septic tank sanitation systems
Based on discussions with the biogas private sector and institutions (users) the initial investment costs for a septic tank based sanitation system are about 1/2 of a biogas digester based system. The exploitation and maintenance costs are estimated to be 1/5 of the exploitation and maintenance costs for biogas digesters.

Table 6: Estimates of investment, exploitation and maintenance costs for septic tank sanitation systems

Cost Estimates for septic tank sanitation systems	Large system	Small system
Initial investment costs as ratio of biogas digester costs	1/2	1/2
Annual exploitation and maintenance costs as ratio of biogas digester exploitation and maintenance costs (>three years)	1/5	1/5

4.4 Costs savings gained by institutions with biogas systems

As explained above we have only taken into account two types of direct cost benefits:
1. *Savings on emptying septic tank (desludging)*
2. *Savings on cooking fuels*

The costs for cooking fuels and desludging and the average population have been gathered from a number of institutions. The data collected has been normalised to represent the proposed biogas systems, with 1,000 and 4,000 people respectively. The average, low and high expenses on fuel and desludging were determined for each category of institution as shown in the tables below. Unfortunately the researchers have not been able to collect data from small schools.

Table 7: Normalized annual expenditure on firewood and emptying septic tanks for small prisons (1,000 inmates)

Expenses small prisons	High	Low	Average	Unit
Sanitation expenses	51,200	2,743	22,431	GHC
Fuel expenses	25,200	20,022	23,305	GHC

Table 8: Normalized annual expenditure on firewood and emptying septic tanks for large prisons (4,000 inmates)

Expenses large prisons	High	Low	Average	Unit
Sanitation expenses	280,922	46,080	163,501	GHC
Fuel expenses	211,321	74,400	142,860	GHC

Table 9: Normalized annual expenditure on fuel and emptying septic tanks for large schools (4,000 students)

Expenses large schools	High	Low	Average	Unit
Sanitation expenses	102,099	70,892	86,496	GHC
Fuel expenses	63,301	123,077	93,189	GHC

Sanitation cost savings

The major financial impact (on cost savings) of a biogas plant is the reduction in expenditure for emptying conventional septic tanks. Since a properly designed and maintained biogas system would not require desludging, the savings on desludging are assumed to be the same as the current expenditure on desludging in the institution. As can be seen in the tables above, the amounts spent on desludging vary widely. We have not been able to find out the reason(s) for this wide variation.

Fuel cost savings

Financial benefits for the institutions furthermore result from actual cash savings due to reduced purchases of cooking fuel. The value of the fuel expenditure savings is dependent on the amount of biogas generated, the amount of fuel being used by the institutions and the cost of purchased fuel. The fuel cost saving is estimated based on the assumptions as shown in Table 3.

4.5 Payback period

Substitution of a septic tank system by a biogas digester system

When replacing their current septic tank based system, the payback period for institutions was estimated using average, best and worst case scenarios. The average case is using the calculated average cost of the systems and also the average expenditure on sanitation and fuel for each category of institution. The best case (optimistic) considers the lowest cost of the system and the highest expenditure while the worst case considers the highest cost of the biogas plant against the lowest expenditure on sanitation and fuel. Table 10 shows the results of the analysis for each category of institution. No depreciation costs for the currently used septic tank system have been taken into account in this calculation.

The payback period for the institutions ranges from 1 – 5.7 years for the best case scenarios. For the average scenario the payback period ranges between 4.2 and more than 25 years and for the worst case scenario all payback periods are more than 15 years.

Table 10: Payback period for institutions when substituting septic tank sanitation systems

Prisons with 4,000 inmates	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**4.2**	**1**	**30.5**
15%	**7.5**	**1.1**	**54.7**
25%	**10.0**	**1.3**	**74.2**
Prisons with 1,000 inmates	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**10**	**1.7**	**>>>**
15%	**18.5**	**2.5**	**>>>**
25%	**25.9**	**3.7**	**>>>**
Boarding Schools with 4,000 students	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**7.2**	**2.5**	**14.8**
15%	**13.2**	**4.1**	**27.9**
25%	**18.6**	**5.7**	**38.7**

Green cells: payback < 5 years; Orange cells: payback 5-10 years; Red cells: payback > 10 years

"Green field" situation

In a "Green field" situation a biogas system is installed instead of a septic tank based system. When calculating the payback period only the additional investment and maintenance and operation costs of a biogas digester, compared with a septic tank system, will have to be used.

Table 11: Payback period for institutions in a "Green Field" situation – a newly built sanitation system

Prisons with 4,000 inmates	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**2.0**	**0.4**	**12.7**
15%	**2.9**	**0**	**23**
25%	**4.0**	**0**	**32**
Prisons with 1,000 inmates	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**4.4**	**0.8**	**>>>**
15%	**7.8**	**0.5**	**>>>**
25%	**11.0**	**0.6**	**>>>**
Boarding Schools with 4,000 students	**Payback time (years)**		
Discounting rates	*Average case*	*Best case*	*Worst case*
0%	**3.3**	**1.2**	**6.6**
15%	**5.5**	**1.5**	**12.1**
25%	**7.8**	**2.0**	**17.0**

Green cells: payback < 5 years; Orange cells: payback 5-10 years; Red cells: payback > 10 years

The payback periods for all institutions are less than 2 years for the best case scenarios for all discounting rates. For the average case they range between 2 and 11 years. For the worst case scenario only the boarding schools with 4,000 students seem to have a reasonable business case with a payback period of 6.6 years.

4.6 Other financial and economic benefits

Financial benefits for institutions

For the cost-benefit analysis only the cost saving for the reduced use of fire wood (a very conservative estimate of the savings has been used) and the absence of desludging the septic tanks are taken into account for the institutions. However the institutions might have additional costs savings or higher costs savings in the near future. These are:

> *The costs for desludging and cooking fuels are likely to increase.*
> *Costs for water use. The digester provides water for irrigation of gardens and / or lawns.*
> *Costs for fertilizer or increased yield from vegetable and fruit gardens. The digester provides organic fertilizer, replacing artificial fertilizer or increasing yield.*

Economic benefits for the community / society

For the community or society as a whole, there are a number of economic benefits:

> *Reduced medical and health (also absence from work) related costs: The preparation of food requires less or no fire wood anymore, reducing the problems caused by the smoke. Also the effluent of the digester is free of any harmful pathogens reducing the number of people getting sick (as the waste is often not properly being disposed of).*
> *The reduction in use of firewood reduces forest degradation. Forest can be used for other purposes with a financial benefit.*
> *Building biogas digesters is labour intensive and requires enhanced skills of labourers, thereby qualitatively and quantitatively increasing employment and economic activities in general.*
> *There is a significant reduction in carbon dioxide emissions.*

As stated before these societal benefits have not been taken into account in the above cost-benefit analysis.

4.7 Conclusions

Although the used data have rather wide ranges, it seems there is a business case for biogas digester systems as an alternative for the currently used septic tank systems. This is especially the case if a new system has to be built (“Green Field”). For institutions wanting to replace a septic tank with a digester system, the payback periods are less optimistic. However no depreciation costs for the currently used septic tank system has been taken into account in these calculations. The typical technical lifetime of a septic tank is 30 years. The actual payback periods for currently used systems will range between the ‘substitution situation’ and the ‘green field situation’, depending on the age of the system currently in use.

The researchers used a very conservative approach to calculate the financial benefits of a biogas digester. Only two benefits, wood fuel replacement and reduction of desludging costs, have been taken into account and the amount of biogas produced can be considered as a very conservative estimation.

What is clear from the cost-benefit analysis is:

> *Discounting rates have a huge influence on the economic viability of biogas digester systems.*
> *The reduction of the desludging costs are the most important cost savings for institutions.*
> *The cost of a digester system in Africa is much higher than compared with South-East Asia, which has a negative impact on payback period.*
> *Additional data gathering, providing data with less wide ranges, will improve the reliability of the cost-benefit analysis. Data should be gathered on:*
  - *Quotations of biogas digester systems;*
  - *Estimates of comparable septic tank systems;*
  - *Desludging costs savings and energy costs savings for institutions.*

  Additional data gathering on the benefits of using the effluent for irrigation and fertilising will give a more realistic (and also better) picture of the benefits of biogas systems.
> *Biogas digesters have many more financial and non-financial benefits but these have not been taken into account in this cost benefit analysis.*
> *Large prisons seem to have the best business case.*

5. Readiness of the biogas private sector in Ghana

The design and construction of a biogas system takes time and requires knowledgeable and skilled people. As an example, it takes about 30 days to build a 40 m^3 biogas digester (fixed dome) for a school of 140 students. The following table presents a breakdown of the work to be done. About 2/3 of the labour needed is unskilled and 1/3 skilled.

Table 12: Amount of work to be done constructing a 40 m^3 fixed dome biogas digester

Activity	Number of days	Number of workers
Digging of earth (dome and expansion chamber)	4 days	2 (Unskilled)
Laying of bricks and plastering of dome	15 days	5 (3 unskilled)
Closing of dome	5 days	3 (2 unskilled)

The anticipated 200 systems to be implemented, requires a sufficient number of private sector companies and skilled masons. Is the Ghana biogas private sector ready to implement these 200 systems in a 5 year period?

5.1 Previous experiences with readiness of the biogas private sector

In 2007 the Ghana government initiated some studies on the set-up, planning and development of a nationwide biogas programme. A pre-feasibility study conducted by the Kumasi Institute of Technology and Environment (KITE), revealed the highest potential for domestic biogas systems to be in the three Northern regions and the Ashanti Region. A follow-up study [35] by KITE assessed the feasibility of pursuing a market based, enterprise-centred approach to the large scale deployment of domestic biogas plants in rural Ghana with emphasis on the three northern regions and the Ashanti Region. The main conclusions, related to the readiness of the Ghanaian biogas private sector were:

> *There is very little in-country experience with regards to domestic biogas plants as the majority of existing biogas plants are bio-sanitation projects located in urban centres.*

> *The current supply chain for biogas digesters is weak and characterised by few entrepreneurs located in two major cities. The manpower base (the number of trained technicians/artisans) is also weak and appears inadequate to handle huge volumes of demand for the digesters.*

Based on the KITE report it was concluded that commercialisation of domestic biogas systems in the survey area in particular and Ghana in general, was not feasible at that time. The question is if this situation has changed in recent years:

1. *Is there sufficient in-country experience with regards to institutional (or similar sized systems) biogas-sanitation systems?*
2. *Is there a good supply chain for biogas digesters?*

5.2 Ghanaian private companies active in biogas digestion and sanitation

Several Ghanaian private companies and institutions have been involved in the design, construction, maintenance and operation of biogas sanitation systems in Ghana in the last 10-15 years. They are responsible for the construction of at least 400 biogas systems in institutions, hotels, government buildings and homes[15]. Based on desk research and discussion with biogas stakeholders, the following organisations have been identified (see table below). For some it is unclear if they are still active and / or involved in biogas systems. The level of expertise and experience differs widely among the organisations mentioned.

Table 13: List (incomplete) of organisations that have been involved in the design and construction of biogas sanitation systems in Ghana in the last 15 years

Organisation	Year founded	Type of biogas technology
Beta Construction Engineers Ltd (BCEL), Accra	2006 *	Puxin
Biogas Technologies Ltd (BTAL) previously Biogas Technology West Africa Ltd, Accra	1994	Fixed dome
Biosanitation Company Ltd (BCL), Obuasi	1998	Fixed Dome + Floating Drum
Centre for Energy, Environment and Sustainable Development (CEESD), Kumasi	2013	Fixed Dome + Floating Drum
Environmental Impact Technology Ltd, Obuasi	2002	Fixed Dome
Global Renewable Energy Services	1996	Fixed dome
Institute for Industrial Research (IIR), Accra	1986	Fixed dome
Renewable Energy and Environmental Systems	2002	Fixed dome
RESDEM	1996	Bio-latrine
Biogas Engineering Limited (BEL), Kumasi	2002	Fixed dome
Apana solutions ltd, Accra	?	Fixed dome
Koajay Company Limited, Accra	?	Fixed dome
Environmental Impact Ltd, Obuasi	?	Fixed dome
Abu Biogas Construction Limited (ABCL), Obuasi	?	Fixed Dome + Floating Drum
Unireco	2001	Fixed dome
Technology for Improved Environment (TIE) – defunct	?	?
Biogas construction Ltd	?	?
Tropical Energy Resources	?	?

* Started biogas plant construction in that year, the company is older.

[15] Several studies show lists of biogas plants that have been constructed in Ghana. See for example the following references [2], [3], [14],

5.3 Discussions and meetings with the biogas private sector

As part of the study the researchers met with seven private biogas companies for individual interviews (see Annex A). During these interviews the following topics have been discussed:

> *Company profile: products and services, year of operation and experience with (institutional biogas) in Ghana and abroad.*
> *Technical details of institutional biogas systems; design, construction, maintenance and operation.*
> *Costs of institutional biogas systems.*
> *Providing services (e.g. maintenance and operation) and contractual arrangements.*
> *Capacity for implementing many biogas systems.*
> *How to implement a national biogas programme; timing, selection criteria for institutions and geographical focus.*
> *Interest in cooperating / participating in a national institutional biogas programme.*

All seven expressed their interest in cooperating / participating in a national institutional biogas programme. Six of the seven private companies also were present at both stakeholder workshops (see annex B), all having an important contribution in the discussions.
The six companies present in both stakeholder workshops seem very motivated, have a good knowledge base and are very experienced. They have constructed between 10-100 biogas systems each.

During both workshops the need for a biogas industry organisation was expressed (and supported by all private company participants) to strengthen the sector. During the second stakeholder workshop a first initiative has been launched to start discussions amongst the private sector organisations. The Ghana Energy Commission expressed its intention to facilitate these meetings.

5.4 Conclusions

The biogas private sector in Ghana seems ready to design, construct and maintain and operate 200 biogas systems in a few years' time.

> *There are about 10 companies and organisations in Ghana having a great deal of experience with the design, construction and maintenance and operation of biogas systems.*
> *At least 6 companies have built between 10-100 systems each.*
> *The knowledge base and technical experience of these 6 is good to very good, based on:*
- *Detailed technical discussions with each of them*
- *Field visits to some of their projects*
- *Talking to actual clients / users*

> *The 6 companies seem very motivated to be engaged in a national programme for institutional biogas*

6. Policies and public initiatives relevant for institutional biogas

Ghana has not yet instituted a national biogas programme. The only document which specifically mentions a national target for the implementation of biogas systems is the Sustainable Energy for All (SE4ALL) Action Plan (2012) which seeks to conduct a feasibility study and establish institutional biogas systems for 200 boarding schools, hospitals and prisons by 2019.
A number of policies and public initiatives are relevant for institutional biogas and its implementation.

6.1 Renewable Energy and Climate Change policies

The strategic National Energy Plan (2006) proposes to increase the use of renewable energy sources to 10 percent of the national energy mix by 2020. The plan recognises the fact that establishment of a feed-in tariff regime that is friendly to renewable energy and backed by regulatory framework is necessary to accelerate the development of renewable energy for electricity generation. The Public Utility Regulatory Commission (PURC) in 2013 published the feed-in tariffs for renewable energy sources.

Also, the Ministry of Energy and Petroleum in its revised National Energy Plan (2009) provides direction on how to reverse the decline in the fuel wood resource base of the country and further sustain its production and use by improving the efficiency of production and use. The Plan suggests that, government should "*Promote the production and use of improved and more efficient biomass utilization technologies and the use of modern biomass energy resources through creation of favourable regulatory and fiscal regimes and attractive pricing incentives*".

The draft bioenergy policy [27] also seeks to maximise the benefits of bioenergy on a sustainable basis. The policy targets, objectives and strategies which the development of institutional biogas could facilitate include:

> *Use of municipal wastes for energy purposes;*
> *Promotion of private sector participation in the bioenergy industry;*
> *Provision of an avenue to reduce poverty and wealth creation through employment generation;*
> *Reduce carbon dioxide emissions.*

Biogas is mentioned specifically, targeting the sanitation problems in the country.

In promoting renewable energy in general, the government of Ghana has demonstrated its commitment in meeting these targets by passing the renewable energy law (ACT 832) in 2011 which is expected to create a favourable platform for development of green energy and low carbon options. The RE Act 832 also establishes the renewable energy fund part which the Energy Commission hopes to utilize to promote the development of biogas in Ghana.

Also, promotion of small and medium-sized enterprise (SMEs) participation in institutional biogas technology penetration has been identified as one of the five key priority energy related

National Appropriate Mitigation Actions (NAMAs) in Ghana. This is in line with the country's pursuit for low carbon development options which is identified in the national climate change policy (2014) as well as the sustainable development objectives articulated in GSGDA. The waste-to-energy policy objective as stipulated in the GSGDA is to convert most of the wastes generated in municipal, urban, rural, industrial and agricultural activities to energy with the strategy of maximising energy production from waste.

6.2 Sanitation and development policies

Ghana recognizes the significance of improved sanitation and has thus outlined strategies for same in the GSGDA I which are re-emphasized in GSGDA II. Strategies aimed at improving environmental sanitation include the following:

1. *Promoting the construction and use of appropriate and affordable domestic latrines;*
2. *Support public-private partnership in solid and liquid waste management;*
3. *Promote cost-effective and innovative technologies for waste management; and*
4. *Develop disability-friendly sanitation facilities.*

Though the various developmental interventions (GPRS II, GSGDA I and GSGDA II) do not directly mention biogas as a means of enhancing sanitation, some of the policy strategies provide a platform for the development of sanitary biogas systems to promote good sanitation. For instance, biogas systems can be used to improve household and **institutional sanitation** as outlined in the strategy and can also be used to replace the improved pit-latrine technologies such as the Ventilated Improved Pit (VIP) and the Kumasi Ventilated Improved Pit (KVIP) which have been used as main technologies for public toilets in Ghana [14].

6.3 Other policies and initiatives

According to EPA officials, EPA has acts in place stating that new public buildings will not receive a building permit when utilising septic tank sanitation systems.
Also EPA has a role in monitoring the efficiency of biogas systems and the quality of the effluent of biogas systems. The costs associated with this monitoring and the unavailability of sufficient budget obstructs a proper execution of these tasks by EPA.

In 2012 the governments of Korea and Ghana started a cooperation project "Supporting green industrial development in Ghana: biogas technology and business for sustainable growth", supported by UNIDO. This project is focussed on industrial application of biogas systems but can have an impact on large scale sanitation biogas systems, maybe in combination with other industrial and/or agricultural feedstock.

In September 2014 the United Nations Development Programme (UNDP) and partners have launched an initiative to consolidate the partnership between the Government of Ghana, UNDP and Governments of China and Denmark on Renewable Energy Technology Transfer. The initiative aims to facilitate the development and transfer of renewable energy technologies from

China to Ghana along with the support required to make the technologies actually work on the ground.
The project is expected to have a tremendous impact on increasing access to energy for the rural poor in Ghana. It focuses on technologies such as solar and wind for irrigation, biogas, mini hydro and improved cook stoves and will have private sector development as its centrepiece. The four-year project is a key component of UNDP's support to the implementation of Ghana's SE4All action plan.

6.4 Conclusions

A number of different Ghanaian policies are supportive to the implementation of biogas sanitations systems but without being very concrete. The SE4ALL action plan is the only policy plan specifying objectives and activities targeting (institutional) biogas.
The SE4ALL action plan will end its activities latest in 2019.

Development, implementation and enforcement of new policies / legislation is necessary to address:

> *Stimulating the implementation of biogas systems instead of septic tanks for new buildings and institutions.*

> *The risks of implementing biogas systems on a large scale:*

- *Ensuring the effluent meets the standard for pathogenic level;*
- *Ensuring the biogas is used and not emitted without flaring.*

7. Stakeholders for institutional biogas in Ghana

In the course of the research done, several stakeholders have been identified that can have an important role in furthering the stimulation and implementation of institutional biogas in Ghana. Based on discussions with the stakeholders (see Annex A), this chapter describes the potential role(s), for each group of stakeholders, to further stimulate institutional biogas in general. In chapter 9, specific roles per stakeholder are described for setting-up and implementing a National Programme for Institutional Biogas.

7.1 Governmental institutions

As institutional biogas is targeting a number of objectives and sectors, a number of government organisations need to be involved in activities aimed at furthering the stimulation of institutional biogas in the country. The identified government institutions are provided in the following table.

Table 14: Governmental stakeholders relevant for Institutional Biogas in Ghana

Governmental institutions	
Ministry of Energy and Petroleum (MoEP) *	Ministry of Education (MoE)
Energy Commission (EC) *	Ghana Education Service (GES)
Ministry of Local Governments and Rural Development (MLGRD)	Ministry of the Interior (MINT)
Ministry of Environment, Science, Technology and Innovation (MESTI) *	Ghana Prisons Service (GPS) *
Environmental Protection Agency (EPA) *	Ministry of Health (MOH)
Ministry of Trade and Industry (MOTI) *	Ghana Health Service (GHS) *

* Already involved in the course of this project

The Ministries have an important role in the development of supportive policies, the related enforcement mechanisms and assigned budgets. GPS, GHS and GES have a role in the practical organisation of activities, when their respective institutions are being targeted.
GPS has indicated, in the discussions with the researchers, to be very interested to take the biogas initiative further. GPS does have both skilled staff and unskilled labourers available that can be used for the construction of the biogas digester, thereby reducing the investment costs. Also there might be an opportunity to get the necessary funding, for the investment costs, from the Ministry of Interior.

The Energy Commission has taken the initiative for this project and has indicated (during the stakeholder workshop on 8th October) to be willing to be the lead organisation, to further the implementation of institutional biogas in Ghana, in close cooperation with other main stakeholders like MESTI, MoEP and EPA.

7.2 Biogas construction organisations and private sector associations

In chapter 5 we have already discussed the biogas companies (including the Institute for Industrial Research), active in Ghana. They have a role in the design and construction of biogas installations and also in maintenance and possibly in operation of these systems. In addition the private sector association 'Ghana Alliance for clean cookstoves' should play a role, especially in the organisation of the sector, focussing on setting standards and quality control.

Text block 5: The Ghana Alliance for clean cookstoves (www.cleancookstovesghana.org)

The Ghana Alliance for clean cookstoves has been established as a strong stakeholder platform to lead the front to catalyse a revolution in the cookstoves sector and mobilize high level national and donor commitments towards the goal of universal adoption of clean cookstoves and fuels in Ghana. Our ambitious target to foster the adoption of clean cookstoves and fuels by 4 million households in Ghana and distributing 5 million cookstoves by 2020 has generated interest from a wide range of private, public and non-profit stakeholders. The unprecedented consultative process with the global cook stoves sector has led to the development of the sector strategy for achieving its goal. By providing a roadmap for concerted action and measurable results that can quite literally change the lives of nearly 25 million Ghanaians in the country and become a beacon of example for the west African sub-region, the strategy will foster a unified vision for the sector while building a common sense of engagement by all stakeholders on the most critical actions required for universal adoption of clean cook stoves and fuels.

The Ghana Alliance aims to strengthen local actors working in the cookstoves sector, support government to achieve its renewable energy policy and climate change program goals and increase consumer awareness on the importance of fuel efficient and clean cookstoves. The Alliance could potentially act as the central coordinating body to provide support and ensure effective implementation of cookstoves programs in Ghana.

7.3 Local NGOs

A number of local NGOs focus on sanitation and biogas. The following three have been involved in the course of this project:

> *Kumasi Institute of Technology, Energy and Environment (KITE)*
> *ABANTU for development*
> *Centre for Energy, Environment and Sustainable Development (CEESD)*

Other NGOs potentially interested in biogas sanitation systems are:

> *Friends of the Earth Ghana*
> *Nature Conservation Research Centre West Africa*

The role of participating local NGOs is to ensure local development impacts are sufficiently addressed in plans and activities. They also can play a role in the effective communication with user groups and monitoring of local impacts.

7.4 Donor and international development organisations

Efficient biomass use for energy purposes is getting more and more attention worldwide but specifically in West Africa, as traditional biomass use is still very high with all negative impacts associated with it. In addition sanitation is a major topic in West Africa in general and in Ghana specifically, with the recent outbreak of cholera in the Accra region.
A large number of donor and development organisations focus on these two topics, either separately or in combination. Often private sector development is a crucial element of the implementation strategy of the development objectives. The following donor and international development organisations have been identified to potentially play a role in institutional biogas sanitation systems in Ghana.

Table 15: Donor and international development organisations relevant for Institutional Biogas in Ghana

Organisations	
DANIDA *	Embassy of the Kingdom of the Netherlands to Ghana *
USAID *	Embassy of France in Ghana
SNV *	Embassy of Japan in Ghana
GIZ *	EU delegation in Ghana *
UNDP *	

* Already involved in the course of this project

The role of these development organisations can vary, depending on their development objectives, strategies and activities. Based on discussions with a number of the organisations they can contribute, either actively or as a funding organisation, to:
> *Private sector development through training and capacity building*
> *Awareness raising amongst institutions and general public*
> *Research and knowledge transfer*
> *Monitoring of results and impacts*
> *The creation of funding mechanisms*

7.5 Research institutes

A number of research institutions are involved in biogas. Institute for Industrial Research (IIR) is probably the organisation with the longest track record in biogas, not only focusing on research but also having a lot of practical experience designing and constructing biogas systems. The following institutes seem to be the most relevant.

The role of these institutes is of course predominantly in research, focussing on:
> *More (cost) efficient and cheaper biogas systems*
> *Developing design, construction, maintenance and operation guidelines and standards*
> *Monitoring of all social and economic benefits*
> *Assess the performance and usability for Ghana of new (for Ghana) biogas technologies as an alternative for the currently used ones*

Table 16: Research institutes relevant for Institutional Biogas in Ghana

Research institutes
Institute for Industrial Research (IIR) *
Kumasi Renewable Energy Centre / Kumasi Polytechnic *
The Energy Centre / Kwame Nkrumah University of Science and Technology (KNUST) *
Valley View University
Council for Scientific and Industrial Research (CSIR)

* Already involved in the course of this project

7.6 Institutions: boarding schools, prisons and hospitals

As public boarding schools, prisons and hospitals are the targeted institutions, they will of course have a role when biogas systems are being implemented. In the development of a programme their role is limited.
When discussing with institutions (see Annex A) the pros and cons of biogas compared with their current sanitation and cooking situation it became clear they are very much in favour of a biogas system, provided they can afford it.
In chapter 8, indicative figures are provided on the number of institutions present in Ghana.

7.7 Private banks and funds and International Financing Institutes

A large number of institutions and funds are actively involved in renewable energy in Africa. The table below presents some of them, based on the researchers´ own experience and contacts and the report from Connect, "funding institutions for energy investment in Africa" [42]. Annex C provides a full list of potential sources of funding for institutional biogas in Ghana.

Table 17: Financing organisations relevant for Institutional Biogas in Ghana

Financing organisations	
World Bank *	African Renewable Energy Access Program (AREAP)
African Development Bank *	Sustainable Energy Fund for Africa (SEFA)
UNDP-GEF *	Swiss International Finance Group AG (SIFG)
EcoBank *	ECOWAS Bank for Investment and Development (EBID)
SOVEC *	African Biofuels and Renewable Energy Fund (ABREF)
Dutch Development Bank (FMO)	The Africa Enterprise Challenge Fund (AECF)
Ventures Africa (Standard Bank)	KfW Green for Growth Fund
African Renewable Energy Fund (AREF)	Angel Investment Network for Green Energy

* Already involved in the course of this project

The organisations that have been contacted by the researchers have stated to be potentially interested in participating in further activities. Each and every organisation has its own focus areas, financing conditions and type of financing. A blended financing mechanism seems most logical for any further activities in the area of institutional biogas.

7.8 Conclusions

Based on the individual discussions with stakeholders and the two well attended stakeholder consultation workshops, it seems there is an urge felt by all stakeholders to take institutional biogas for sanitation a step forward. The participants recommended an interdepartmental approach targeting sanitation, renewable energy, private sector development and agriculture. The Energy Commission will help drive this process in close collaboration with MoEP, MESTI, EPA and other relevant stakeholders.

When starting a National Institutional Biogas Programme, prisons seem to be the institutions of choice when starting a pilot. Ghana Prisons Service is very interested to take the biogas initiative further and they seem to have the willpower and manpower available to make biogas work in practice, both in the short and long run. Also there might be an opportunity to get the necessary funding, for the investment costs, from the Ministry of Interior.

A blended financing mechanism seems most logical for any further activities in the area of institutional biogas.

8. Market potential for institutional biogas systems in Ghana.

The SE4ALL action plan is focussed on implementing 200 institutional biogas systems. However the overarching aim is to develop a sector that is able to flourish by itself bringing the potential benefits to the Ghanaian community. In this chapter we present figures for the three types of institutions - public hospitals, boarding schools and prisons – giving an idea of the overall market for institutional biogas.

8.1 Biogas market for public boarding schools, prisons and hospitals

The market potential for institutional biogas systems in public institutions is estimated based on the number of public institutions in Ghana that satisfy one basic requirement, which is the ability to use the biogas for cooking. This requires that the institutions being targeted must have an in-house kitchen, where cooking is done on a daily basis. Or for example the biogas is used for heating water.

Government institutions that satisfy these conditions are:
> *Senior high schools (boarding);*
> *Senior technical and vocational institutions (boarding);*
> *Colleges of education (Teacher training);*
> *Nursing training schools;*
> *Prisons;*
> *Hospitals;*

Table 18 Number of public institutions and their population [33]

Public institutions	Number of institutions	Population	Biogas potential (1,000 m^3 / year)
Educational centres: [16]			
Senior high schools	474	250,000	900 - 8,000
Technical and vocational schools	23	18,000	70 - 600
Colleges of education	38	20,000	70 - 600
Tertiary education	20	60,000	300 - 2,900
Prisons [17]	45	12,800 - 14,000	100 - 600
Hospitals [18]	110	11,500	60 – 540
TOTAL	**710**	**370,000**	**1,500 – 13,200**

The current figures are probably much higher for all types of institutions.

[16] Ministry of Education, 2003
[17] Wikipedia
[18] Ghana Health Service, 2004

8.2 Biogas market for other institutions and companies in Ghana

Apart from the public institutions mentioned in the previous paragraph, there are many other privately owned institutions which meet the requirements. Also hotels and restaurants generate substantial amounts of kitchen and food waste and human waste that can be converted to biogas for cooking or heating water. The African Regent Hotel is a good example where they use the biogas sanitation system to produce biogas for cooking.

Table 19 Number of other institutions and their population [33]

Other institutions	Number of institutions	Population	Biogas potential (1,000 m^3 / year)
Public schools and universities [19]	161	60,000 *	300 - 3,000
Hospitals [20]	200	10,000	50 – 500
Hotels and restaurants [21]	> 1,500	?	?
TOTAL	**> 1,900**	**?**	**?**

* Rough estimate

8.3 Conclusions

In addition to the foreseen 200 public biogas sanitation systems there is still a huge market for both institutional biogas systems and systems for other user groups like hotels and restaurants. Also other sectors could be targeted, like apartment buildings, offices, gated communities and many others.

In a later stage also sectors can be targeted that require other types of biogas digesters, like households and industrial systems for slaughterhouses and in the food (processing) industry.

[19] Ministry of Education, 2003

[20] Ghana Health Service, 2004

[21] web search

9. A National biogas-sanitation program for public institutions

Based on the feasibility study and the responses (and recommendations) of the stakeholders it is recommended to set-up a National Institutional Biogas Programme with the following objectives:

> *Implement 200 biogas digester systems in public boarding schools, hospitals and prisons and*

> *Kick-start the further development of a biogas market in Ghana.*

9.1 Why a National biogas programme for institutions in Ghana?

Many studies addressing domestic and institutional biogas in Ghana[22], call for a National Biogas Programme, to capture the socio-economic and environmental benefits and overcome the technical, operational, financial and promotional barriers. Such a National Biogas Programme should have a three-pronged focus:

1. *Improve the sanitation situation*
2. *Use biogas for energy purposes*
3. *Use bio-slurry for irrigation and as organic fertilizer*

Benefits of a National Biogas Programme

In chapter 4 the costs and benefits for institutions are presented and although the figures are not fully conclusive it seems there is a decent business case for the involved institutions. This is in line with figures from other studies, although it should be noted that these have focussed on domestic biogas systems [39]. Examples of estimated benefit-cost ratios are presented in the following table.

Table 20 Benefit-cost ratios of National Biogas Programmes for Households and Society [1]

	Benefit-cost ratio for households *	Benefits-cost ratio for society
Sub-Saharan Africa	1.22	6.38
Uganda	1.25	6.84
Rwanda	1.32	5.57
Ethiopia	1.35	4.52

* Including subsidy

The number 1.22 in the above table, for Sub-Saharan Africa, means that every dollar (or any other unit of money) invested by a household in a biogas system, results in 1.22 dollar of economic benefit (over the period of the programme; in this case 15 years).

In chapter 3 all the socio-economic and environmental benefits are presented, both for institutions and the society as a whole. The socio-economic benefits for institutions are much

[22] e.g. literature [3], [26], [28] and [35]

higher than represented in the cost-benefit analysis in chapter 4, as many benefits have not been monetised. The benefit-cost ratios in Table 20 are somewhat better, taking into account:

> *Cooking and lighting fuel savings*
> *Time saving due to biogas*
> *Saving in household's health related expenditures*
> *Income effects of improved health*

The social and environmental benefits of institutional biogas for society as a whole are also described in chapter 3 (see Figure 8 and Figure 10). Table 20 presents the economic value of these benefits. In the case of an integrated National Biogas-Sanitation Programme in Sub-Saharan Africa **every dollar invested in such a programme results in 6.38 dollar of economic benefit** (over the period of the programme; in this case 15 years). The benefits that have been monetised are:

> *Cooking and lighting fuel savings*
> *Chemical fertilizer saving*
> *Time saving due to biogas and latrine (fuel collection, cleaning and cooking, latrine access)*
> *Savings in health-related expenditures*
> *Time savings due to improved health*
> *GHG reduction*
> *Local environmental benefits*

Biogas programmes running in Cambodia, Bangladesh and Nepal have shown similar results.

Previous feasibility assessments of a National Institutional Biogas Programme?

A study performed by KITE in 2008 [35] assessed the feasibility of pursuing a market based, enterprise-centred approach for the large scale deployment of domestic biogas plants in rural Ghana with emphasis on the three northern regions and the Ashanti Region. The main conclusions of this study are included in the text box below.

Text block 6: Summary of the main conclusions of the KITE feasibility assessment report [35]

- *The anticipated market potential does not yet exist and will have to be developed.*
- *Technically it's possible to install in about 80,000 households, at least one 6m3 fixed dome digester, to take care of their daily cooking energy needs.*
- *The investment costs for a fixed dome digester in Ghana is several times higher than in several Asian and Eastern African countries where the technology has been commercialised.*
- *These high costs result in a negative payback time over the 15 years lifespan of the digester (assuming an interest of 10% compared).*
- *There is very little in-country experience with regards to domestic biogas plants as the majority of existing biogas plants are bio-sanitation projects located in urban centres.*
- *The current supply chain for biogas digesters is weak and characterised by few entrepreneurs located in two major cities. The manpower base (the number of trained technicians/artisans) is also weak and appears inadequate to handle huge volumes of demand for the digesters.*

Based on this study it was concluded that commercialisation of domestic biogas systems in the survey area in particular and Ghana in general was not feasible at that moment.

The KITE report also concluded that the decision to invest in biogas technology should not only be based on the profitability or otherwise of the investment since the non-direct financial benefit to the household. The overall benefits to society at large provide the economic justification for public intervention that will create the necessary enabling environment to kick-start the development of the domestic biogas market. Therefore it was recommended to initiate a social business model focusing on technical training, business development, financing and market facilitation as its main components and based on the concept of private-public partnership (PPP) as the way forward for Ghana towards harnessing and commercialising its biogas potential.

The current situation is entirely different.

> *Most importantly the anticipated National Biogas Programme (NBP) is focussed on institutional biogas instead of domestic biogas systems.*
> *The pay-back times of the installations seem much shorter than 15 years, whilst system cost reductions are very likely when a well-functioning market for biogas has been developed.*
> *More than 400 biogas systems have been built in Ghana.*
> *A sufficient number of knowledgeable and experienced entrepreneurs (with trained technicians) is already active in the biogas market.*

The justification for public intervention (see also previous paragraph) is still valid.

9.2 Objectives for a National Institutional Biogas Programme in Ghana

The initiative for the feasibility study on institutional biogas started from the SE4ALL action plan. The specific activity formulated within the SE4ALL action plan is "*to conduct a feasibility study to establish institutional biogas systems for 200 boarding schools, hospitals and prisons*" with 2012-2015 as implementation timeline. The purpose of this activity is to bring the use of biogas as a low carbon energy source to a significantly higher level in Ghana. The 200 systems therefore should kick-start the development of the biogas market and should stimulate and accommodate further implementation of biogas digesters in the country. Biogas digesters, not only for institutions but also for other market sectors and end-users, like hotels, restaurants, apartment buildings, offices, gated communities, households and industrial systems for slaughterhouses and in the food (processing) industry.

Barriers to be tackled by a Ghanaian National Institutional Biogas Programme
A number of barriers[23] obstruct the development of a well-functioning biogas market in Ghana, thereby depriving the entire country of all the socio-economic and environmental benefits associated with the use of biogas digester systems.

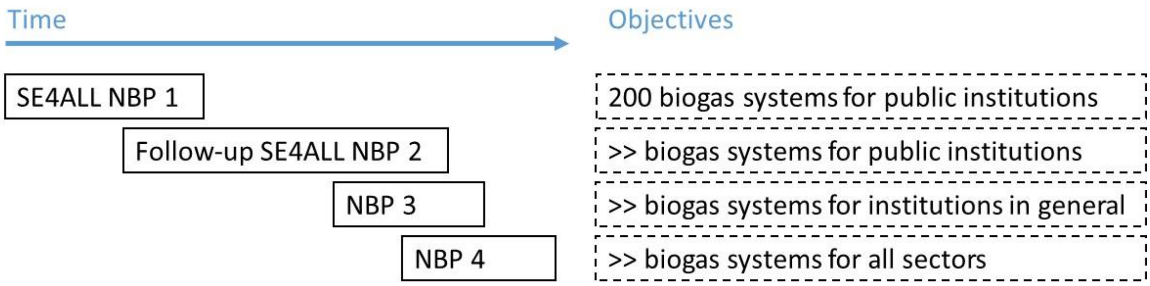
[23] See for example literature [3], [34], [35] and [36]

These barriers are:
> *Little market demand for digesters*
> *High construction cost of biogas digesters (compared to other countries)*
> *Limited private sector development*
> *Lack of maintenance and operation services for digester systems*
> *Lack of financing mechanisms for institutions (and other users) to pay high upfront costs*
> *Lack of appealing examples of biogas digesters which excellently show the benefits*
> *Lack of a national promotion programme*
> *Lack of quality standards for biogas digesters and control mechanisms to ensure quality and sustainability of the systems built*
> *Lack of a governmental focal point for biogas digestion ensuring the integration of biogas in energy, environmental, sanitation and agricultural policies*

Multiple National Biogas Programmes?

The purpose of the SE4ALL biogas activity is to bring the use of biogas as a low carbon energy source to a significant higher level in Ghana. The 200 systems should kick-start the development of the biogas market and should stimulate and accommodate further implementation of biogas digesters in the country. The SE4ALL activity, implemented in the first National Biogas Programme (NBP 1), is likely to be followed-up by programmes extending the successful implementation of biogas in the country. This can be visualised as presented in the following figure.

Figure 12 Possible consecutive biogas programmes in Ghana



9.3 Experiences from existing national biogas programmes

From the experience of biogas technology dissemination in developing countries, it is obvious that biogas promotion cannot be left in the hands of private companies alone. The direct involvement of government and state institutions in biogas promotion has been an important success factor in countries such as China[24], India[25], Cambodia and Nepal[26]. Cooperation between

[24] GTZ Biogas - country reports. Biogas Digest, Volume IV, Information on Advisory Service on Appropriate Technology (ISAT), Eschborn, Germany, 1999.
[25] Aggarwal D. Biogas plants based on nightsoil. TERI, New Delhi, India, 2003.
[26] Silwal B.B. A Review of the biogas programme in Nepal. Winrock International Research, Report series No. 42, BSP Lib Temp No. 72, p.52, Nepal, 1999.

the state and the private sector has led to the development of favourable policies and regulatory frameworks that have ensured a sustained growth of the biogas sector.
The success story of the technology dissemination in the above countries 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.

Text block 7: Experiences from the Cambodian National Bio digester Programme [39]

Since the early 1990s international development organisations – often in cooperation with the national government – have attempted to introduce biogas technologies in many least developed countries, but most initiatives failed. In this landscape of failed biogas development programmes the National Bio digester Programme (NBP) Cambodia started in 2006, with the aim to establish a permanent market oriented and self-financed biogas sector. The results show the development of a sustainable domestic bio digester sector, a rapid diffusion of bio digesters among poor rural households, but still ambivalences on financial independency from external funding and carbon finance. The conclusion is that a pure market model for biogas development in the rural area of the least developed countries will not easily work. Governmental regulation and coordination will remain needed, and carbon finance will not easily fully replace ODA and governmental financial support.

9.4 Important elements of a Ghanaian National Biogas Programme for public institutions

Based on the feasibility study and the many discussions with all stakeholders, a number of important elements have been identified for a National Institutional Biogas Programme (NIBP), facilitating the implementation of the 200 institutional biogas systems. These elements are:

- *A long-term objective: a self-sustaining biogas market in Ghana (see Introduction)*
- *An interdepartmental approach targeting sanitation, renewable energy, private sector development and agriculture (see chapters 2, 3 and 7 and paragraph 9.1)*
- *A multi-year programme addressing the barriers as stated in paragraph 9.2*
- *Start with pilot institutions most likely to be successful (see chapters 3, 4 and 7)*
- *A well-balanced stakeholder involvement (see chapter 6 and 7)*
- *Blended programme funding (see chapter 7)*

A long-term objective: a self-sustaining biogas market in Ghana

The SE4ALL objective for the implementation of 200 biogas installations in public institutions is not a target in itself but merely a means of kick-starting the development of the biogas market in Ghana. This is expected to bring the use of biogas as a low carbon energy source to a significant higher level in Ghana and also provide all the previously described benefits to the country.

An interdepartmental approach

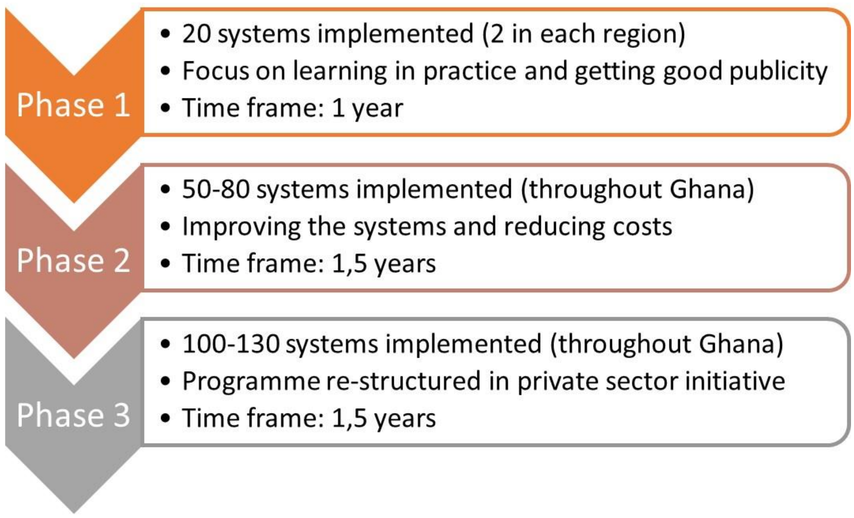
In previous chapters it has become clear that only an approach targeting sanitation, renewable energy, private sector development and agriculture will be able to capture all benefits (social, economic and environmental) and simultaneously be able to successfully address all risks and challenges. To ensure a sound and coherent coordination, one public organisation should take the lead in this approach. The Ghana Energy Commission has indicated (during the stakeholder workshop on 8th October 2014) to be willing to take on this role.

Figure 13 Important elements for a National Institutional Biogas Programme (NIBP)

A multi-year programme addressing the different identified barriers

Based on the feasibility study, the discussions with stakeholders and experiences from other National Biogas Programmes, a four year National Institutional Biogas Programme (NIBP) is foreseen with three distinct phases.

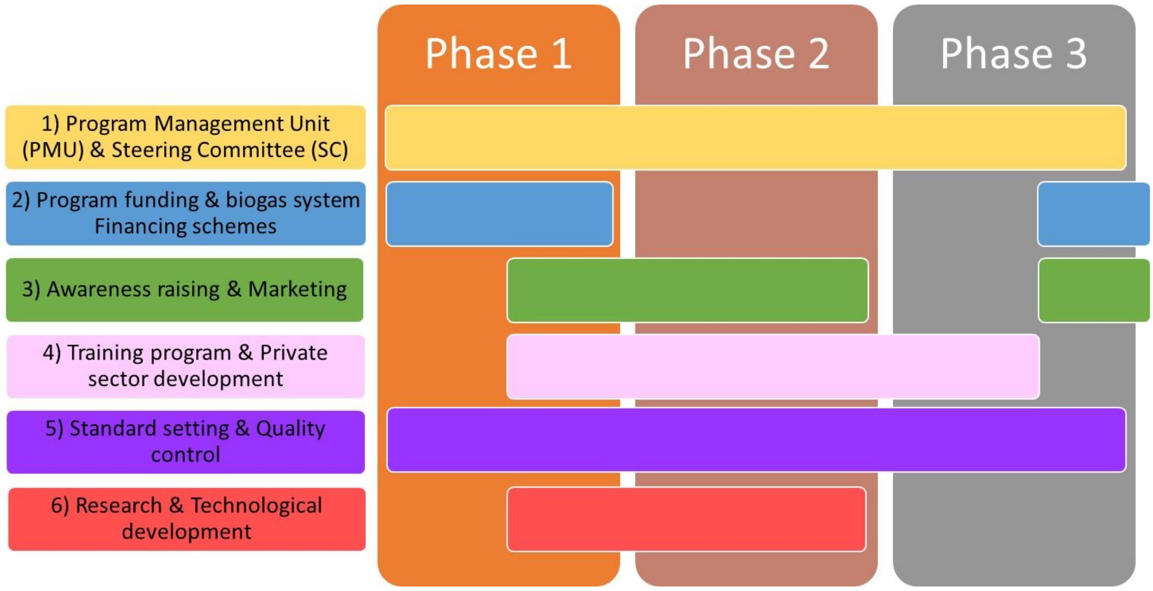
Figure 14 The three suggested phases for the Ghanaian NBP



Activities structured under 6 activity lines

Based on other National Biogas Programmes in both Asia and Africa and the barriers to be tackled in Ghana to further the development of a well-functioning biogas market in Ghana, six activity lines are proposed for the NIBP. The following figure presents these activity lines and their interrelations with the three phases.

Figure 15 Structure and timing of major activities for the Ghanaian NIBP



In paragraph 9.6 the involvement of the different stakeholders per activity is presented.

Start with pilot institutions most likely to be successful

For a successful start of a National Institutional Biogas Programme it is advised to start the implementation of the first 20 biogas systems with pilot institutions most likely to be successful, which inter alia implies that they should be able to utilize all potential socio-economic, environmental and financial benefits. This is:

> *Good for publicity and marketing*
> *Good for all stakeholders involved*
> *Most cost-efficient and*
> *Will provide the necessary information to be able to assess the positive impacts.*

The selection criteria for the institutions in phase 1 are:

1. *Financial commitment from institutions throughout the technical lifetime of the system*
2. *Institutions willing and committing to use both biogas and effluent*
3. *Institutions willing and committing to operate the plant (after training) / or pay a service provider to do it.*

Large prisons and agri-schools seem the most promising at this stage.

9.5 Funding of a National Biogas Programme for public institutions

Based on the discussions with several stakeholders and experiences of existing National Biogas Programmes a blended funding mechanism is the most likely form of funding. What also has become clear from the discussions with the public sector, financial sector and private sector, the programme should not be donor driven but should have a large share of private sector involvement (including funding).

Cost of a National Biogas Programme

The costs of a National Biogas Programme for the implementation of 200 biogas systems are:

1. *Costs for financing / funding the 200 biogas systems.*
2. *Program costs related with the six identified activity lines.*

In the SE4ALL CAP, the costs of the 200 installations (including training of local artisans for construction and maintenance of equipment and education and sensitisation of beneficiary institutions) was very roughly estimated at 50 million dollar. This seems rather high.

Using the quotations that have been provided by the biogas construction companies the overall costs for a National Institutional Biogas Programme for the implementation of 200 systems is estimated at 20 million USD. For this estimation the following numbers have been used:

> *the average construction costs for 20 systems for 4,000 people and 180 systems for 1,000 people*
> *Additionally, 20% overhead for all programme related activities.* [27]

The costs of the biogas-sanitation systems are too high for the majority of the beneficiaries to pay up-front (except maybe in the case of a new structure that is going to be built). Even if institutions are capable of paying the up-front cost it seems that not many are willing to do so. The cost-benefit analysis clearly shows that institutions will have significant cost savings, which they can use to pay for the biogas digester system in periodic instalments. The cost of installations can in that case partly be paid by institutions up-front and partly be subsidised or financed.

The height of the subsidy or the length of the financing period, depends on the cost and benefits of a biogas digestion system. In chapter 4 these costs and benefits have been calculated, however the results are not very reliable due to poor data availability and quality – further research is required to ensure that the calculations are based on reliable data.

Funding of a National Biogas Programme

The funding of a National Biogas Programme can come from several sources:

> *Donor and international development organisations*

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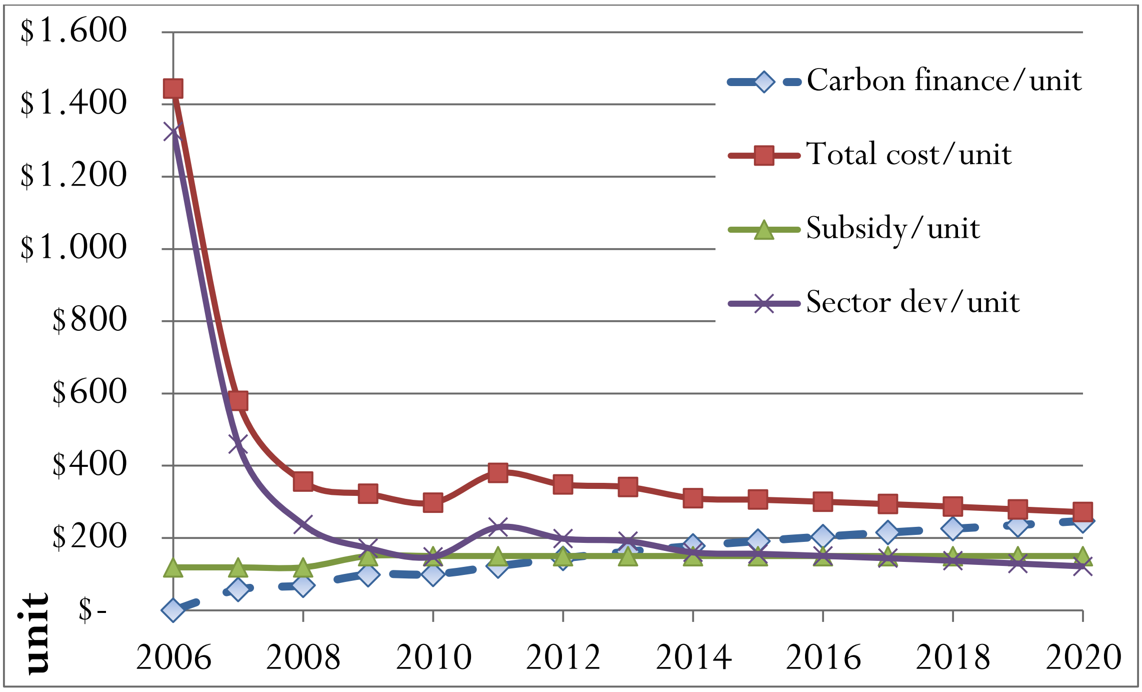
[27] Based on the report "A COST-BENEFIT ANALYSIS OF NATIONAL AND REGIONAL INTEGRATED BIOGAS AND SANITATION PROGRAMS IN SUB-SAHARAN AFRICA" the overhead costs are seem to vary between 6-16% of the total costs.

> *Private banks and International Financing Institutes*
> *Local and international funds*
> *The institutions (beneficiaries) themselves*
> *Local government*

Annex C presents a long list of potential sources of funding for the National Biogas Programme in Ghana.
The researchers have discussed with several potential funding organisations whether they would be interested in participating in the programme. All have expressed their interest in (part of) the programme but also expressed the need for a structured financial plan, including a cash-flow analysis.

Carbon funding
As has been shown in other National Biogas Programmes throughout Asia and Africa, carbon funding is not sufficient for setting-up a full-fledged national biogas programme. Carbon funding might be an additional funding component and might be sufficient to bear the costs of a fully developed and running national biogas programme (after 5-8 years) [34].

Figure 16 Impact of carbon financing on the Cambodian Biogas Programme [Eric Buysman, 2014]



Carbon funding can yield sustainable long term output based funding and it is the only alternative to ODA for programme financing. But carbon finance, due to high transaction costs, needs an economy of scale and it is also the most unreliable and challenging form of financing, due to:

> *The volatile market conditions and constantly changing methodologies*

> *Regulatory uncertainty on the carbon markets*
> *Monitoring and follow-up is very labour intensive and requires specific knowledge*
> *The need for significant upfront finance*
> *Prices on compliance market are very low and it is unsure if this will change in the near future.*

The UNFCCC focal point for Ghana advised the researchers not to investigate the possibilities for carbon financing for setting-up a National Biogas Programme, confirming that carbon financing is a possibility after a programme has been put in place and when long-term funding is needed for securing the sustainability of a programme.

The conclusion is that a pure market model for biogas development in the rural area of the least developed countries will not easily work. Governmental regulation and coordination will remain needed, and carbon finance will not easily fully replace ODA and governmental financial support. It is debateable whether this is problematic, as biogas markets also provide a lot of socio-economic benefits and many more markets (fossil energy) are stimulated (subsidised) by governments.

9.6 Stakeholders and their possible roles

The following table present the possible roles of the different stakeholders when carrying out a programme to implement 200 institutional biogas systems.

Table 21: Possible roles for stakeholders in a National Institutional Biogas Programme

Programme activity	Stakeholders
1) Program Management Unit & Steering Committee (including policy development and enforcement)	Energy Commission (lead organisation), MESTI, MoEP, EPA, Ministry of Health, Ministry of Education and Ministry of Interior
2) Program funding & biogas financing schemes	Financing organisations, donor and international development organisations
3) Awareness raising & Marketing	Energy Commission, GPS, GHS, GES (and related Ministries)
4) Training program & Private sector development	Donor and international development organisations and national Research Institutes
5) Standard setting & Quality control	Research Institutes, MESTI, MoEP and EPA
6) Research & Technological development (including impact monitoring)	Research Institutes and local NGOs
Biogas construction	Private sector, boarding schools, hospitals and prisons

9.7 Conclusions

Summarising the above chapter, the following conclusions can be drawn:

> *A number of barriers obstruct the development of a well-functioning biogas market in Ghana*
> *The socio-economic and environmental benefits of institutional biogas for the society at large outweigh the costs by far.*
> *A purely market driven approach for biogas development in Ghana will not work. The direct involvement of government and state institutions is an important success factor.*
> *The anticipated 200 systems should kick-start the development of the biogas market in Ghana.*
> *Blended funding is needed for a National Biogas Programme; carbon finance will not easily fully replace ODA and governmental financial support.*
> *Many relevant stakeholders are enthusiastic about a National Institutional Biogas Programme in Ghana and are potentially interested to participate / support the Programme but have expressed the need for a structured financial plan, including a cash-flow analysis.*

9.8 Recommendations

Based on the feasibility study and the recommendations from the stakeholders, the researchers formulated 5 main recommendations.

1. *Start a National Institutional Biogas Programme (NIBP) with the following objectives:*

> *Implement 200 biogas digester systems in public boarding schools, hospitals and prisons*
> *Kick-start the further development of a biogas market in Ghana.*

The NBP should contain the following elements:

> *A long-term objective: a self-sustaining biogas market in Ghana*
> *An interdepartmental approach targeting sanitation, renewable energy, private sector development and agriculture*
> *A four year programme with 3 phases*
> *Activities structured under 6 activity lines*
> *Start with pilot institutions most likely to be successful*
> *A well-balanced stakeholder involvement*
> *Blended programme funding*

To be able to set-up and implement such a National Institutional Biogas Programme (NIBP) the following four activities need to be carried out.

2. *A more detailed inventory of user needs and cost-benefit analysis*

Unfortunately the inventory of user needs and the data for the cost-benefit analysis shows too much variation. Therefore the following activities are proposed:

> *Inventory of the user needs for a biogas system and the current costs for sanitation, cooking fuels and, if relevant, fertilisers (30-50 schools, 10 prisons and 20 hospitals throughout the country and preferably evenly spread over the 10 regions)*

- *Meetings with Ghana Prisons Service, Ghana Health Service / Min. of Health and Ghana Education Service / Min. of Education, to select institutions and agreement on how to approach the institutions*
- *Set-up and carry out user needs and costs inventory with institutions*

> *Set-up and collect more detailed cost estimates for biogas systems*
> *Verify collected data and analyse results*

The expected result is a solid cost-benefit analysis report.

3. ***Financial analysis and structuring of the programme in parallel with institutional structuring***

The following activities are proposed:

> *Securing the regulatory framework, procedures/rules and mandates are in line with intended programme (several meetings with relevant governmental organisations), e.g. schools are allowed and able to invest in a biogas system*
> *Discussions with biogas private sector on the financial analysis and structuring of the programme and assessment of their ability and willingness to engage with the proposed structuring*
> *Prepare financial (cash-flow) and operational scenarios for the programme*

The expected result is a proposal how to financially structure the programme. The actual fundraising is not part of this work.

4. ***Draft a detailed programme plan and secure funding***

The following activities are proposed:

> *Select the first most appropriate institutions.*
> *In close cooperation with the Energy Commission a first programme plan is drafted*
> *The plan and financial structuring is discussed with potential donors and supporters*
> *The programme is adapted to the needs of donors and supporters*
> *Funding and support is officially requested by the Ghana Energy Commission from the selected donors /supporters*

The expected result is a detailed programme including secured funding and support from international donors.

5. ***Secure potential funding and support for biogas from UNDP and GEF***

Try to get biogas as a priority into strategic plans (and budgets):

> *UNDP / Energy Commission strategic plan for 2015-2016*
> *GEF / MESTI strategic plan for 2015-2020*

All the above recommendations and activities have been confirmed by the participants of the stakeholder meeting of 8th October 2014 as organised by the Energy Commission.

Annex A. Meetings and Interviews

The following table presents all the meetings and interviews from 18-29 August 2014.

In total 41 visits and / or interviews have been held, of which 36 where successful (resulting in meaningful feedback and / or information). The experts met with 43 different people, relevant for this study, not taking into account the workshop organised on 27 August (with 30 participants) and the KREC stakeholder meeting (with over 30 participants).

Organisation	Name	Date and time
Energy Commission, SE4ALL secretariat	Mrs. Paula Edze	18 August, 09:00
Energy Commission	Mr. Kwabena Ampadu Otu-Danquah	18 August, 09:00
Energy Commission	Dr. Nii-Darko K. Asante	18 August, 11:00
Ministry of Energy and Petroleum	Mr. Wisdom Ahiataku-Togobo	18 August, 12:00
Ministry of Energy and Petroleum	Mrs. Gifty Tettey	18 August, 12:00
School near EU		18 August, 14:00
EU delegation Ghana	Mr. Simon Rolland	18 August, 15:00
Kumasi Polytechnic	Mr. Edem Bensah	19 August, 09:30
Centre for Energy, Environment and Sustainable Development	Mr. Edward Antwi	19 August, 10:30
Biogas Engineering Limited (BEL), Kumasi	Dr. Aklaku	19 August, 12:00
KITA	Mr. Samuel Owusu-Takyi	19 August, 15:00
Kumasi Central Prison	Commander	20 August, 10:00
Kumasi Polytechnic	stakeholder meeting establishment Kumasi Renewable Energy Centre	20 August, 12:00
Environmental Impact Limited	Mr. Daniel Osei-Bonsu	20 August, 14:00
Kumasi Anglican Senior High School	Head master and Administrator	20 August, 15:00
Kumasi central hospital	Administration	20 August, 16:00
Accra Psychiatric Hospital	Administrator	21 August, 10:00
Achimota Senior High School	Headmistress	21 August, 12:00 26 August, 9:00
GIMPA	Mr. Lawrence K Avevor	21 August, 15:00
Tema International High School	Administrator	22 August, 09:00
SafiSana (Ashaiman)		22 August, 10:30
Central University College		22 August, 11:30
Ashaiman Senior High School	Mrs. Beatrice Mensah	22 August, 13:00
Tema Secondary High School		22 August, 15:00

Organisation	Name	Date and time
Environmental Protection Agency (EPA)	Mr. Antwi-Boasiako Amoah	25 August, 09:00
Environmental Protection Agency (EPA) / UNFCCC Focal Point	Mr. Kyekyeku Yaw Oppong-Boadi	25 August, 10:00
Agykot Company Limited www.agyakot.com	Mr. Samuel Agyapong	25 August, 12:00
Koajay Company Limited (Accra)	Mr. Charles Anan	25 August, 15:00
Achimota Senior High School	Headmistress	26 August, 9:00
Accra Girls Senior High School	Headmistress	26 August, 10:30
Accra High School	Administrator	26 August, 11:30
Embassy of the Kingdom of the Netherlands to Ghana	Mr. Fred Smiet	26 August, 14:00
Kumasi Institute of Technology, Energy and Environment (KITE)	Mr. Ishmael Edjekumhene	26 August, 16:00
Kumasi Institute of Technology, Energy and Environment (KITE)	Mr. Christopher Agyekumhene	26 August, 16:00
CSIR-IIR (Institute of Industrial Research)	Dr. Moses Duku	27 August, 13:00
Apana solutions ltd	Mr. Kwasi Twum	27 August, 14:00
Apana solutions ltd	Mrs. Obuafo Alnice	27 August, 14:00
Energy Commission, SE4ALL secretariat	Mrs Paula Edze	27 August, 16:00
SNV Ghana	Mr. Lovans Owusu-Takyi	28 August, 08:30
Beta Construction Engineers Ltd	Rev. Kofi Ahenkorah	28 August, 11:00
GIZ	Mr. Samuel Adoboe	28 August, 14:00
GIZ	Mr. Leslie M Aglanu	28 August, 14:00
Energy Commission	Mr. Kwabena Ampadu Otu-Danquah	28 August, 16:00
Biogas Technologies Limited	Dr. John Idan	29 August, 09:30
Ghana Prisons Service	Mr. E.Y. Adzator	29 August, 12:00
Ghana Prisons Service	Mr. Godwin Hoenyedzi	29 August, 12:00
EU delegation Ghana	Mr. Simon Rolland	29 August, 14:30

Table presenting all meetings and interviews from 30 September - 9 October 2014.

In total 25 visits and / or interviews have been held, of which 20 where successful (resulting in meaningful feedback and / or information). The experts met with over 40 different people, relevant for this study, including the workshop organised on 8 October 2014 with 33 participants.

Organisation	Name	Date and time
Energy Commission	Mr. Kwabena Ampadu Otu-Danquah	30 September, 13:00 1 October, 11:00 9 October, 13:00
MISTI	Mr. Peter Dery	1 October, 10:00
Eco Bank	Mr. Mark Ofori Kwafo	1 October, 13:00
CTI Pfan / Power Africa	Mr. Albert Boateng	1 October, 15:00
Danida	Mr. Lars Joker	2 October, 11:00
UNDP Ghana	Mr. Paolo Dalla Stella	2 October, 13:00
Energy Commission, SE4ALL secretariat	Mrs. Paula Edze	3 October, 09:00 7 October, 12:30
UNEP GEF-SGP	Mr. George Ortsin	7 October, 09:00
World Bank	Mrs. Carol Litwin	7 October, 11:00
Energy Commission	Dr. Alfred K. Ofosu Ahenkorah	7 October, 13:00
Ghana Prisons Service	Mr. Godwin Hoenyedzi	8 October, after WS
Ghana Health Service	Mr. Emmanuel K-Amoah	8 October, after WS
Ghana Prisons Service	Mr. E.Y. Adzator	8 October, after WS
EPA / UNFCCC Focal Point	Mr. Kyekyeku Yaw Oppong-Boadi	8 October, 16:00
EU delegation Ghana	Mr. Simon Rolland	9 October, 11:00
African Development Bank (AfDB)	Mr. Thierno Bah	9 October, 14:00
Biogas Technologies Limited	Dr. John Idan, Director	9 October, 16:00
SOVEC Investment company	Mr. Paul van Aalst	10 October, 16:00

Annex B. Stakeholder consultation Workshops

As part of the assignment, two stakeholder consultation workshops have been organised:

1. Workshop 1, 27 August 2014, 09:00-12:00, STEPRI, Accra
2. Workshop 2, 8 October 2014, 09:00-12:00, Best Western hotel, Accra

First biogas stakeholder consultation Workshop 27 August 2014

Nr	Organisation	Name
	Government Institutions	
1	Energy Commission	Mr. Kwabena Ampadu Otu-Danquah
2	Energy Commission	Mr. Okai Emmanuel
3	Energy Commission, SE4ALL secretariat	Mrs. Paula Edze
4	Energy Commission	Mrs. Sandra Nyaaba
5	Environmental Protection Agency (EPA)	Mrs. Florence Agyei
6	Environmental Protection Agency (EPA) / UNFCCC Focal Point	Mr. Kyekyeku Yaw Oppong-Boadi
7	Ghana Health Service	Mr. Emmanuel K-Amoah
8	Ghana Prisons Service	Mr. E.Y. Adzator
9	Ghana Prisons Service	Mr. Godwin Hoenyedzi
10	CSIR-IIR (Institute of Industrial Research)	Dr. Moses Duku
11	Ministry of Energy and Petroleum	Mr. Wisdom Ahiataku-Togobo
12	Ministry of Energy and Petroleum	Mrs. Doris Duodu
13	Ministry of Environment, Science, Technology and Innovation	Mr. Peter Dery
14	Ministry of Trade and Industry (MOTI)	Mrs. Jane A Mensah-Onumah
15	Ministry of Trade and Industry (MOTI)	Mrs. Afia Gyambea Amouko
	Academia	
	CSOs	
16	ABANTU for Development	Mr. Kofi Karikari
17	Kumasi Institute of Technology, Energy and Environment (KITE)	Mr. Christopher Agyekumhene
	Private Sector	
18	Apana solutions ltd	Mr. Kwasi Twum
19	Apana solutions ltd	Mrs. Obuafo Alnice
20	Beta Contruction Engineers Ltd	Rev. Kofi Ahenkorah
21	Biogas Technologies Limited	Dr. John Idan
22	Biogas Engineering Limited (BEL), Kumasi	Dr. Aklaku
23	Consultant	Dr. Essel Ben Hagan
24	Environmental Impact Limited	Mr. Daniel Osei-Bonsu
25	Environmental Impact Limited	Mrs. Joyce Kwafo

Nr	Organisation	Name
	Development Partners	
26	GIZ	Mr. Samuel Adoboe
27	GIZ	Mr. Leslie M Aglanu
28	SNV Ghana	Mr. Lovans Owusu-Takyi
	Financial Institutions and donor organisations	
29	Eco Bank	Mr. Mark Ofori Kwafo
30	UNEP GEF-SGP	Mr. George Ortsin
	Organisers	
31	Partners for Innovation	Mr. E. Hanekamp
32	CEESD	Mr. Julius Cudjoe Ahiekpor

Second biogas stakeholder consultation Workshop 8 October 2014

Nr	Organisation	Name
	Government Institutions	
1	Energy Commission	Mr. Kwabena Ampadu Otu-Danquah
2	Energy Commission	Ms. Dorothy Adjei
3	Environmental Protection Agency (EPA)	Mrs. Florence Agyei
4	Ghana Health Service	Dr. Emmanuel K-Amoah
5	Ghana Prisons Service	Mr. Emmanuel Adzator
6	Ghana Prisons Service	Mr. Godwin Hoenyedzi
7	Institute of Industrial Research, Council for Scientific and Industrial Research (IIR-CSIR) / PSMD	Dr. Moses Duku
8	Ministry of Energy and Petroleum	Mrs. Gifty Tettey
9	Ministry of Environment, Science, Technology and Innovation	Mr. Peter Dery
	CSOs	
10	ABANTU for Development	Mr. Kofi Karikari
11	Kumasi Institute of Technology, Energy and Environment (KITE)	Mr. Christopher Agyekumhene
12	Global Alliance for Clean Cookstoves	Mrs. Sandra Nyaaba
	Private Sector	
13	Biogas Engineering Ltd. (BEL), Kumasi	Dr. E.D. Aklaku
14	Apana solutions Ltd.	Mrs. Obubuafo Allnice
15	Apana solutions Ltd.	Mr. Kwasi Twum
16	Beta Construction Engineers Ltd.	Rev. Nana Kofi Ahenkorah
17	Biogas Technologies Africa Ltd. (BTAL)	Dr. John Idan
18	Impact Environmental Ltd.	Mr. Daniel Osei-Bonsu

Nr	Organisation	Name
19	Impact Environmental Ltd.	Ms. Joyce Kwafo
20	Koajay Company Ltd.	Mr. Charles Annan
21	Koajay Company Ltd.	Mr. Paul Edward Kartey
22	CTI PFAN	Mr. Albert Boateng
23	ECOBANK	Mark O. Kwafo
	Development Partners	
24	Embassy of the Kingdom of the Netherlands to Ghana	Mr. Fred Smiet
25	Embassy of the Kingdom of the Netherlands to Ghana	Mrs. Mariska Lammers
26	GIZ	Mr. Leslie Mawuli Aglanu
27	SNV Ghana	Mr. Lovans Owusu-Takyi
28	UNDP Ghana	Mr. Paolo Dalla Stella
	Organisers	
29	Partners for Innovation	Mr. Emiel Hanekamp
30	CEESD	Mr. Julius Cudjoe Ahiekpor
31	Energy Commission	Mrs. Paula Edze
32	Energy Commission	Mr. Michael Abrokwa

Annex C. Potential sources of funding for institutional biogas in Ghana

Commercial banks
DBSA
Deutsche Bank
EcoBank
First Rand
MunichRe
Rand Merchant Bank
Standard Bank (Ventures Africa)
Standard Chartered Bank
Triodos

DFIs
ElectriFI
Dutch development bank (FMO)
KfW Green for Growth Fund
Norfund

International Financing Institutes
African Development Bank (AfDB)
GEEREF
InfraCo
UNEP
UNDP
World Bank

Local and international private investors
Acumen
Africa Enterprise Challenge Fund (AECF)
AlphaMundi Group Ltd
Angel Investment Network for Green Energy
CTI-PFAN
D-Capital
DOB
Global Villages Energy Partnership International (GVEP)
Grassroots Business Fund (GBF)
NOTS
Persistent Energy Partners
SOVEC
TriLinc Global

Foundations and funds

African Biofuels and Renewable Energy Company (ABREC)
African Renewable Energy Access Program (AREAP)
African Renewable Energy Fund (AREF)
Akuo Foundation
Ashden Awards - International Awards for Sustainable Energy
Ashden Trust – Climate Change
Carbon War Room
Charles Stewart Mott Foundation - International Finance for Sustainability
Ecowas bank for investment and development (EBID)
Energy Access Foundation (EAF)
energy4everyone
French Global Environment Facility (FFEM)
GDF SUEZ Foundation - Energy, Climate, and Biodiversity
Global Alliance for Clean Cookstoves
Good Energies Foundation
Hivos - Green Entrepreneurship
Livelihoods Fund - Funding for Agroforestry, Mangrove Restoration, and Rural Energy
Minor Foundation for Major Challenges - Public Awareness on Climate Change
Oak Foundation – Climate Change
OPEC Fund for International Development (OFID)
Rockefeller Brothers Fund – Climate Change and Clean Energy
Stiftung Mercator - Climate Change
SunFunder
Sustainable Energy Fund for Africa (SEFA)
Swiss International Finance Group AG (SIFG)
The Africa Enterprise Challenge Fund (AECF)
The Clinton Foundation
The Ghana Renewable Energy Fund
The Light Foundation
The Mary Robinson Foundation - Climate Justice (MRFCJ)
The Solarillion Foundation
The SunEdison Rural Energy Fund (SREF)
UNFCCC - Adaptation Fund
USAID - Development Innovation Ventures
Venture Capital for Africa (VC4A)
WB - GEF Projects for Global Environment
WB - GEF Small Grants Program
WB - Global Partnership on Output-Based Aid (GPOBA)
WB - Public-Private Infrastructure Advisory Facility (PPIAF)
Wuppertal Institute - Sustainable Energy Project Support (SEPS)

Annex D. Literature

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