REPUBLIC OF GHANA

MINISTRY OF LOCAL GOVERNMENT AND RURAL DEVELOPMENT **MLGRD**

EMBASSY OF THE KINGDOM OF NETHERLANDS **EKN**

KOMENDA EDINA EGUAFO ABREM MUNICIPAL ASSEMBLY (KEEA)

GHANA NETHERLANDS WATER, SANITATION AND HYGYIENE (WASH) PROJECT

FINAL REPORT

Assessment of workability of plant designs, construction quality assurance, financial viability and facility operation and maintenance (O&M) management

for

Biomethanation Plant in Edina Essaman

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JANUARY 2014

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EXECUTIVE SUMMARY

This report presents a brief evaluation of the Modern Biomethanation Municipal Sewerage Treatment Plant, a pilot project situated on the final waste disposal site at Edina Essaman. The site has been used for the disposal of both liquid and solid wastes by the Komenda Edina Eguafo Abrem (KEEA) Municipal Assembly (MA) since 1987.

The KEEAMA identified the Biomethanation Municipal Sewerage Treatment Plant as one of the quick "gains" project being implemented as part of the Ministry of Local Government and Rural Development (MLGRD) and the Embassy of the Kingdom of Netherlands (EKN), collaboration in the delivery of preparatory activities for the larger project under Ghana Netherlands WASH Programme in five (5) Assemblies: Cape Coast Metropolitan, KEEA MA (Elmina), Ga West, Ga Central, and Ga South Municipal.

Global Renewable Energy Services was selected by the KEEAMA to execute this project on a turnkey basis. The major construction activities specified for project included a bioconversion plant, excess gray water processing plant, digested residues processing plant, biogas generator and an autonomous water supply system.

MDF West Africa Ltd project management advisors services for the "Quick Gains" project, acting in consultation with the Embassy of the Kingdom of the Netherlands in December 2013 contracted WasteCare Ltd to undertake an assessment the Edina Essaman Biometnanation Project. The scope of this consultancy assignment include; conducting a technical assessment of the plant design and providing advice on workability of the choice of treatment system; analyzing the biological, financial and technical process control systems; conducting a quality assurance check of workmanship and quality/durability of construction materials used and making recommendations for sustainable operations and maintenance for the system.

The following work activities were conducted during this evaluation:

1. **Technical Assessment of Plant Designs:** evaluation of unit processes and plant configuration for the anaerobic bio-reactor, gas generation, gas scrubbing and utilization, excess grey water treatment and digested residues.
2. **Quality Assurance of Works Management:** evaluation of construction schedules site organization and construction practices that have a bearing on the durability of the plant components.
3. **Project Budget and Disbursements:** analysis of payments against work done; and
4. **Project Sustainability:** recommendations for ensuring sustainable operation and maintenance management after completion of construction activities.

The above outputs were realized through review of contract documents, field inspections and stakeholder consultations. The list of stakeholders is presented in Appendix A.

Technical Assessment of Plant Designs

The unit processes and plant configuration indicated for the bio-conversion, excess grey water and digested residue treatment will yield the expected by-products i.e biogas and organic soil ameliorant provided optimal conditions are met. However, concerns about lack of proper plant sizing and details of process design, lack of pre-treatment and intake facilities, as well as unit processes redundancy have to be urgently addressed if sustainable operation and maintenance is to be achieved.

Construction Quality Assurance

The design and build contractor has not provided adequate site storage and offices. Construction works is being carried out by small work gangs using labour-based methods. The lack of requisite equipment and machinery for construction activities (such as concrete works, setting out using plumb lines) is likely to compromise work quality. Measurements conducted on site showed that as-built dimensions for the hydro-segregation and excess grey water plant are different from those provided for in the project documentation.

There has not been any strength testing of construction materials since project commenced and so the effectiveness of the use of ordinary cement blocks for the construction of the base of the bioreactor dome, and walls of other units such as the hydro-segregation tank and excess grey water processing tanks cannot guaranteed.

Project Budget and Disbursements

The contractor has made 5 requests covering mobilization, Phase 2 and 3 activities. The contractor has so far received three (3) payments (advance mobilization and two interim payment certificates) totaling GH₵137,872.99. On the balance a number of works activities are behind schedule or not been performed adequately even though payment has been made to the contractor.

Socio-economic and financial Viability

The biomethanation plant has potential benefits for handling wastewater, septage and faecal sludge currently discharged untreated into the environment. The pilot plant size of $5m^3$ handles about 10% of the total estimated cesspit emptier volumes discharged daily at the dump site. Figure ES1 and ES2, below show the potential value-chain and profitability of the project.

Facility O&M Management

The ownership of the completed facility has to be clearly spelt out. The grant from the Embassy of the Kingdom of Netherlands (EKN) was to the KEEA MA and therefore the Assembly's ownership is assumed.

To ensure the continuous and sustainable operation and management of the facility, it is proposed that a Management Committee[1] should be implemented involving the following:

i. The Municipal Assembly
ii. The Edina Essaman community

[1] The Management Committee can be upgraded to a Public-Private-Partnership arrangement involving a private investor if plant expansion is undertaken to receive up to 40 m3 per day of faecal sludge.

iii. The Royal Stool of Essaman

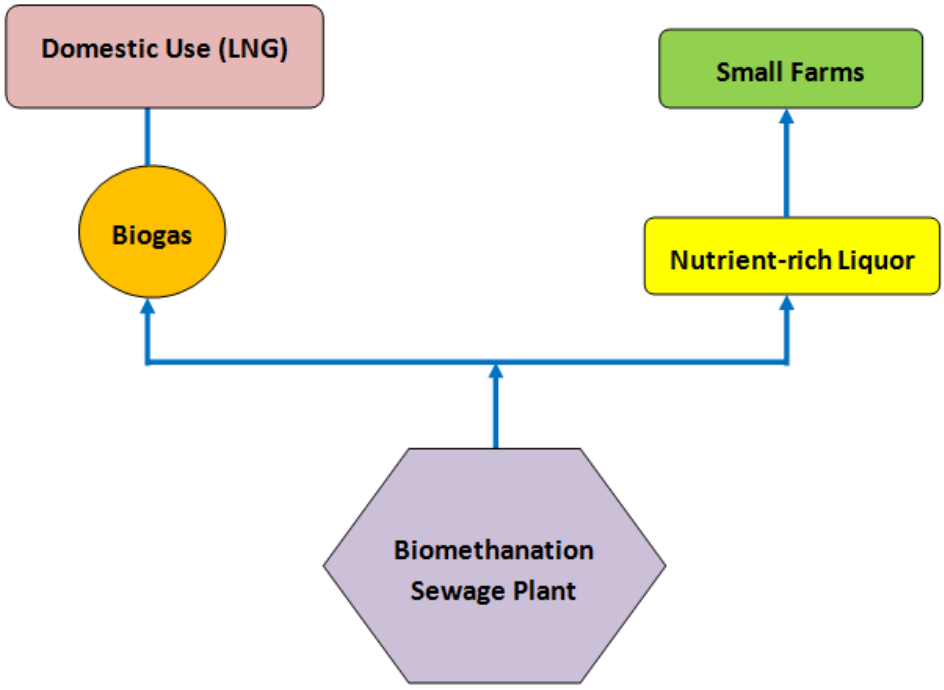
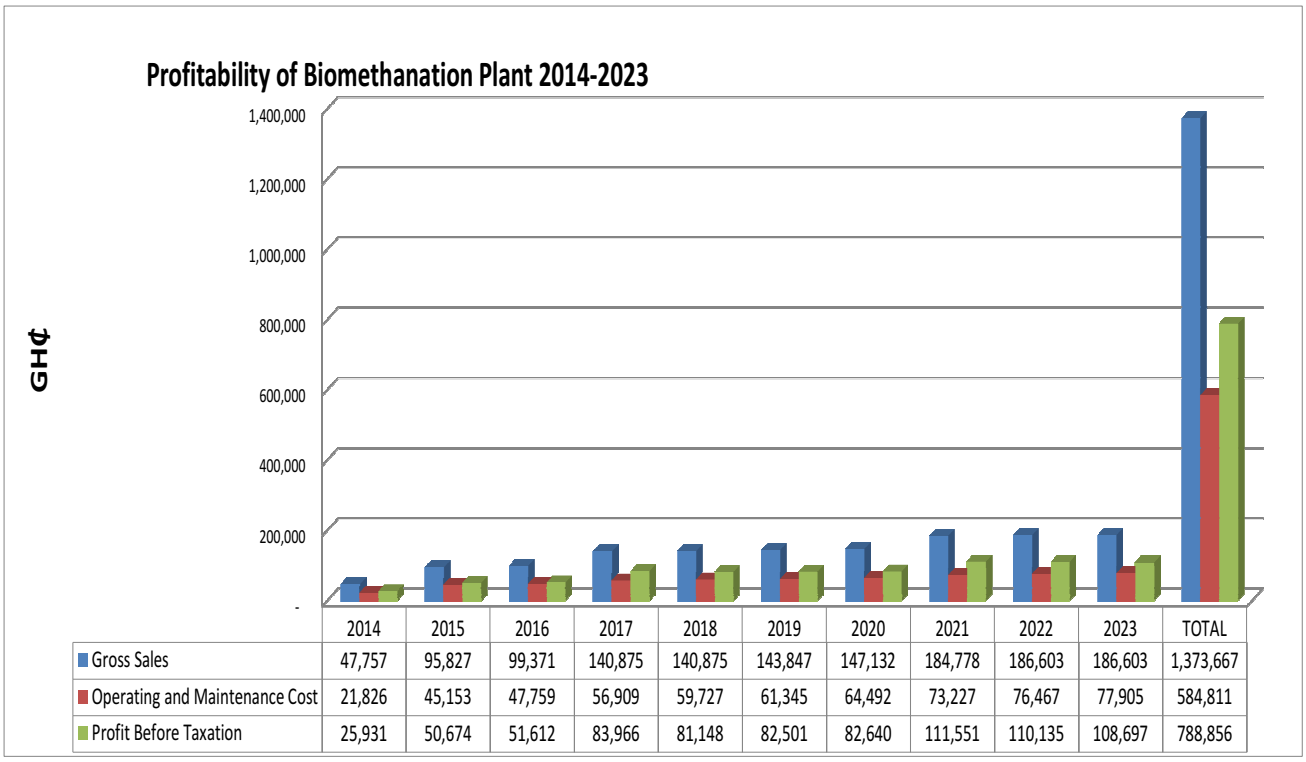


Figure ES1: Value-Chain of Biomethanation Plant



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
Gross Sales	47,757	95,827	99,371	140,875	140,875	143,847	147,132	184,778	186,603	186,603	1,373,667
Operating and Maintenance Cost	21,826	45,153	47,759	56,909	59,727	61,345	64,492	73,227	76,467	77,905	584,811
Profit Before Taxation	25,931	50,674	51,612	83,966	81,148	82,501	82,640	111,551	110,135	108,697	788,856

Figure ES2: Profitability of 5m^3 per day Biomethanation Plant (including borehole water system)

The main recommendations of the assessment are presented in Section 8.0 of this report and a summary is presented in Table ES1.

From the assessment it is concluded that there should be continued support for the project to be completed, commissioned and test-run. This will provide the basis for further assessment of the effectiveness of biomethanation process and the viability of the integrated project.

Table ES1: ASSESSMENT OF BIOMETHANATION PLANT AT EDINA ESSAMAN, KEEA MUNITICPAL ASSEMBLY ELMINA

SUMMARY OF KEY ISSUES AND RECOMMENDATIONS

#	Category	#	Specified Issue	Key Recommendation
1	**TECHNICAL**	1	Site Demarcation and Acquisition of Permits	It is recommended that the boundaries of the biomethanation sewage plant be demarcated and fenced off before completion of the construction works. Additional Infrastructure for site drainage should be provided.
		2	Pre-Treatment Units	The facility should be provided with preliminary treatment units to remove large solids and grits through screening, and ensure hygienic environment during plant operation.
		3	Provision of Detailed Design & Construction Documentation to KEEA MA	The contractor should provide detailed documentation including design reports and engineering drawings as well as details of the procedure for direct discharge of septage/faecal sludge directly into the biodigesters.
		4	Provision of by-pass systems	The contractor should provide flow by-passes consisting of chambers and valves to the digesters to allow for planned maintenance.
		5	Siting of Autonomous Water Supply System	Siting of the borehole for the water supply system should be in accordance with Ghana EPA guideline that requires a minimum buffer distance of 360 m from a waste disposal facility
2	QUALITY ASSURANCE OF CONSTRUCTION WORKS	6	Construction Supervision of Outstanding Works	Remedial action on site organization and construction practices should be carried out and the services of a short-term technical expert procured to assist the KEEA MA in the supervision of the final stages of the construction and test running of the Biomethanation plant.
		7	Completion of Works According to Revised Work Schedule	Bi-monthly site meetings for review of progress of works should be instituted to meet the completion date of 15th March 2014.
3	SOCIO-ECONOMIC AND FINANCIAL VIABILITY	8	Integration of Biomethanation Plant and Water Supply System	To secure the socio-economic benefits of the project, both the Biomethanation and Water supply system should be considered as an integrated project.
		9	Scaling up of the Biomethanation Plant	The pilot plant's capacity of 5 m^3 per day leaves close to 90% of the municipality's untreated septage and faecal sludge being discharged directly into the environment. A scaled-up plant will

				potentially secure more environmental and socio-economic benefits.
4	OPERATION AND MAINTENANCE MANAGEMENT OF THE PLANT	10	Clarification of Ownership of Project	The Ministry of Local Government and Rural Development and the project funding entity (Embassy of the Kingdom of the Netherlands) should communicate the ownership of the project to all interested parties.
		11	Organisational Arrangement for O&M Management	The day-day O&M management of the plant should be provided by a private contractor, and a management committee comprising all key stakeholders formed to oversee the facility operator.

1.0 INTRODUCTION

The Embassy of the Kingdom of the Netherlands is funding the design and construction of a modern biomethanation municipal sewage treatment plant at Edina Essaman in the Komenda Edina Eguafo Abirem (KEEA) Municipal Area as part of project preparatory activities ("Quick Gains Activities") under the Ghana-Netherlands WASH Project. Figure 2.1 shows a location map of the project site.

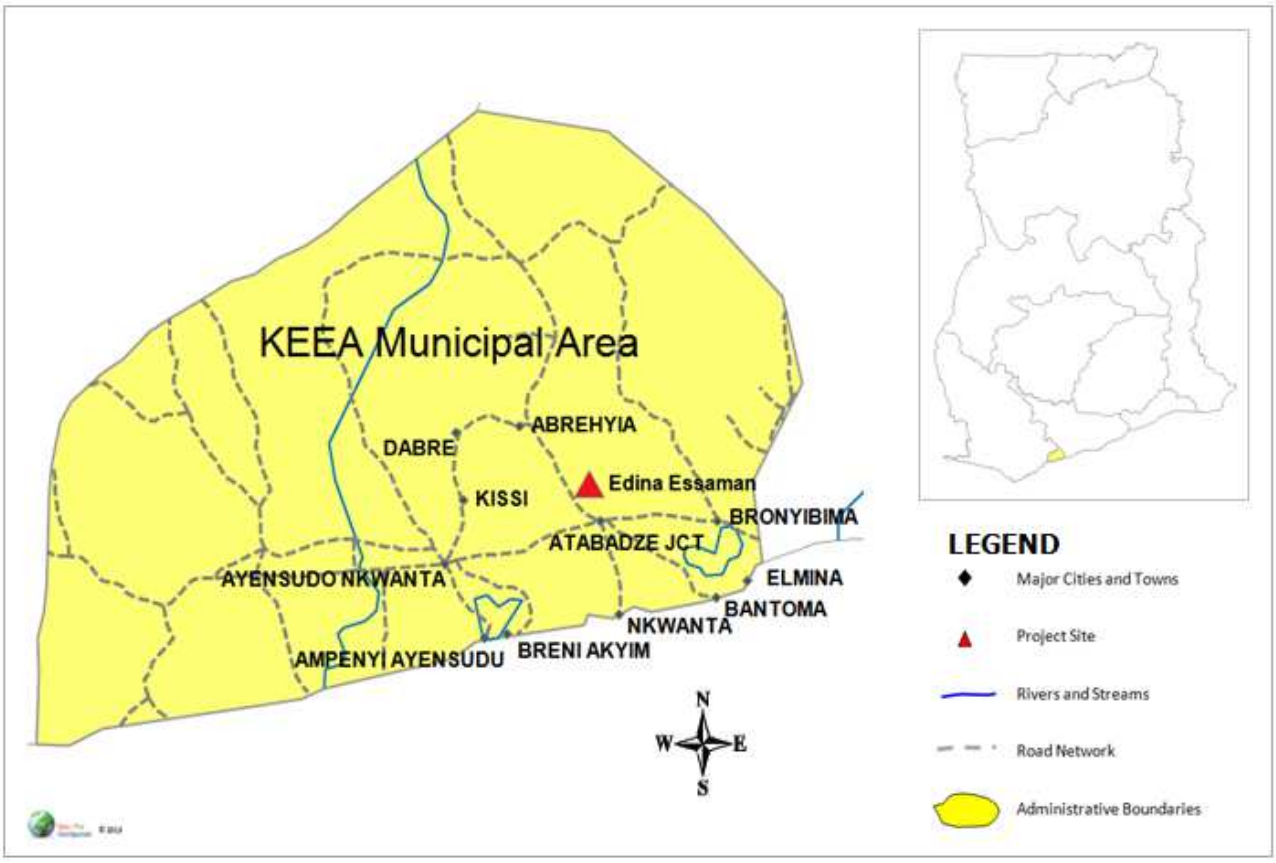


Figure 1.1 Location map of project site

Global Renewable Energy Services was selected by the KEEA Municipal Assembly to execute this project on a turnkey (Design-and-Build) basis. The major construction activities proposed for the modern biomethanation municipal sewage treatment plant included the following:

- Bioconversion Plant;
- Excess Grey Water Processing Plant;
- Digested Residues Processing Plant;
- Biogas Generator;
- Autonomous Water Supply System;

MDF West Africa Ltd in December 2013, acting under the auspices of the Embassy of the Kingdom of the Netherlands, contracted WasteCare Ltd to undertake an appraisal of the Edina Essaman Project. The scope of this consultancy assignment includes;

- Conducting a technical assessment of the plant design and providing advice on workability of the choice of the system;
- Analyzing the biological, financial and technical process control systems,
- Conducting a quality assurance check of workmanship and quality/durability of construction materials used and
- Making recommendations for sustainable operations and maintenance for the system.

This report presents the results of the following work activities;

- Technical Assessment of Plant Designs: Evaluation of unit processes and treatment process trains for biogas generation, excess grey water treatment and digested residues processing.
- Construction Quality Assurance Assessment: Evaluation of construction schedules and site organization and construction practices that have a bearing on durability of the plant components.
- Project Budgeting : Evaluation of payment requests by contractor and
- Stakeholder Consultations: Summary of discussions with various stakeholders on the project including the municipal authorities, beneficiary community and contractor.
- Project Sustainability: Recommendations for ensuring sustainable operation and maintenance after completion of construction activities

2.0 DESCRIPTION OF THE BIOLOGICAL TREATMENT SYSTEMS AND PROCESSES

The Edina Essaman Plant which has a design capacity of $5m^3$/day is an excreta (faecal sludge) facility that comprises of three core treatment systems. These are:

- Biomethanantion Sewage Conversion Plant
- Excess Gray Water Processing Plant
- Digested Residues Processing Plant

A Hydro-segregation tank serves both the biomethanation sewage conversion plant and excess grey water processing plant.

The components of each of these treatment systems and their functions are described in Table 2.1, Table 2.2 and Table 2.3 respectively. The unit processes for each of these treatment systems are also depicted in Figure 2.1, Figure 2.2 and Figure 2.3 respectively

These descriptions are based on both project design report and personal communication with Professor TA Coleman.

Table 2.1 Components and functions of Biomethanation sewage conversion plant

Component	**No.**	**Functions**
Hydro-segregation tank	1	This functions primarily as gravity settling and upflow filtration tank (made up of 4 layers of screens and gauze). The supernatant flows to the biological-bed (bio-bed) and the settled sludge at the bottom flows to the anaerobic reactors. The hydro-segregation tank is covered with a composite plexi-glass (1/3) and steel material (2/3) painted black to enhance heat absorption and retention. It prevents pathogenic (disease causing organisms) emission into the air (aerosol effect) and controls odour.
Anaerobic bioreactor	4	This converts the sewage sludge into biogas, digestate and solid residues. Each bioreactor has inlet and outlets (exit hydraulic expansion chambers)
Gas holder	1	This is used to collect and store the gas from the anaerobic reactors.
Gas plant	1	This is to condition (including scrubbing) the crude biogas prior to utilization.

Table 2.2 Components and functions of excess gray water processing plant

Component	**No.**	**Functions**
Forced convection biological-bed (bio-bed)	1	Enhances the removal of dissolved and suspended organic materials (BOD) and inorganic material. It is also called a mixed-media filtration bed – made up of activated carbon, gravel and sand.
Solar water purification tank	1	This is used to for thermal disinfection and sterilization. The tank has baffles to increase the hydraulic retention and contact time to enhance solar disinfection. It is also covered with a composite of plexi-glass and steel.
Reclaimed water storage tank	1	This is used to store effluent from the solar water purification tank.

Table 2.3 Components and functions of digested residues processing plant

Component	**No.**	**Functions**
Solar pasteurizer	1	This is a disinfection process based on solar radiation absorption. The solar pasteurizer is also covered with composite panel of plexiglass and steel and also serves as a multi-functional dehumidifier, stabilizer and dryer of digested residues.
Drying bed/Residues storage pit	1	This receives digested, disinfected and stabilized residues from the pasteurizer.

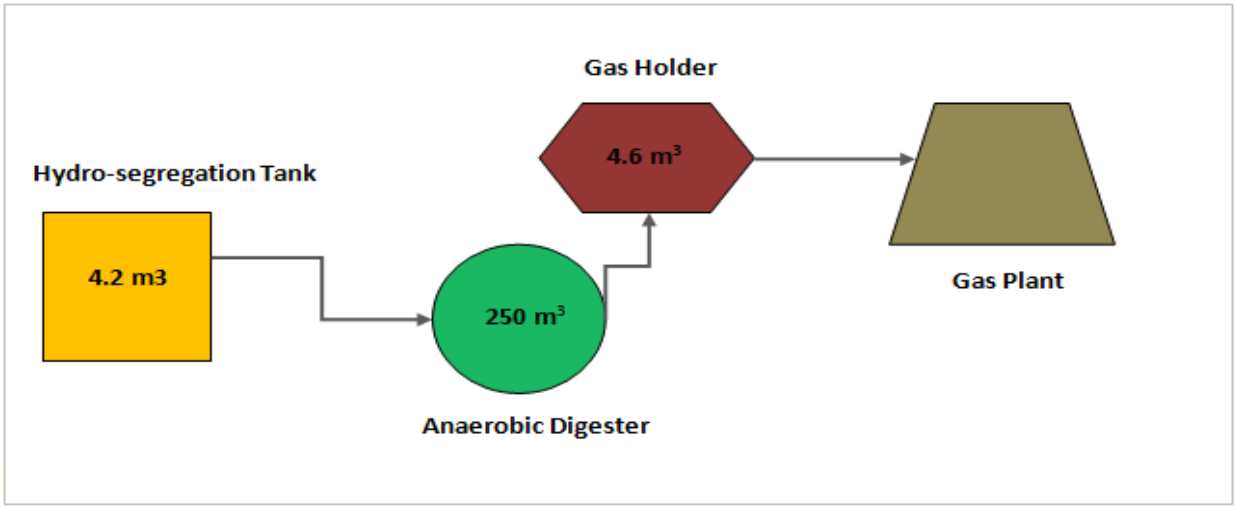


Figure 2.1 Unit processes in biomethanation sewage conversion plant

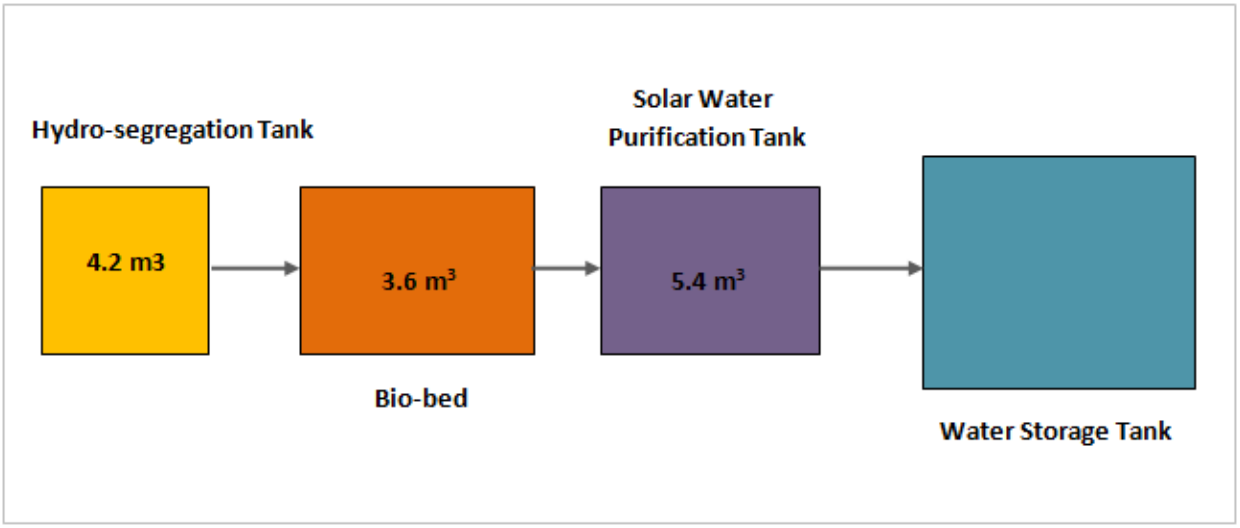


Figure 2.2 Unit processes in excess gray water processing plant

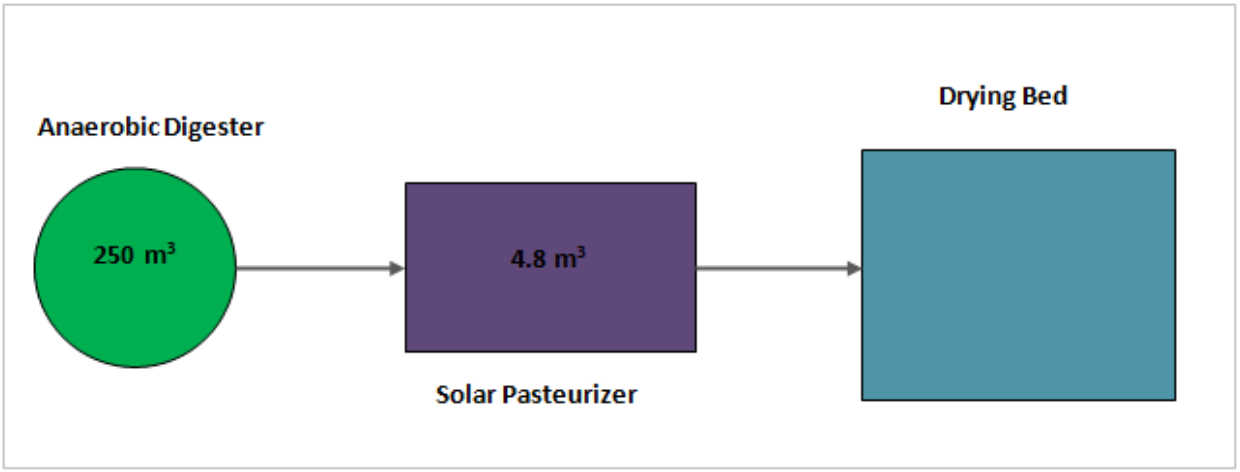


Figure 2.3 Unit processes in digested residues processing plant

3.0 TECHNICAL ASSESSMENT OF PLANT DESIGN

3.1 Workability of Bioconversion Plant and other Appurtenances

This section analyses the technical feasibility of the various unit processes and other appurtenances.

3.1.1 Site Layout

Further and better drawings showing site facilities, infrastructure, positions of appurtenances, vehicle access lanes, parking and waiting areas and buffer zones are required. Dimensions of tanks, pipe diameters or material schedules for the bio-bed, solar water purification and reclaimed water tanks are not clearly shown in the drawings. Additionally there are no hydraulic profiles showing unit process liquid levels and freeboard/ Construction details of concrete ramps vehicle, unloading bays and stopping-blocks, and inlet/outlet structures and descriptions of accessories for gas collection and scrubbing need to be provided.

3.1.2 Excreta (Faecal Sludge) Inlet/Discharge Point (Reception Pot)

The plant is designed to receive $5m^3$ per day ($5m^3/d$) of sewage to be discharged by cesspit emptiers. The emptier trucks will empty into 150 mm (6 inches) reception pot (made of pvc) which is connected to a 125 mm connector PVC pipe that leads to the hydro-segregation tank. The inlet as described does not cater for screening of floating materials (rags, plastics and other bulky non-biodegradable materials such as paper, wood and containers etc).

3.1.3 Hydro-segregation Tank

Concrete is the preferred material which provides adequate corrosion resistance, low permeability and/or durability characteristics required for liquid retention. Furthermore internal structures like baffle will have to be cast monolithically with the main structure at the time of construction. The use of upflow screens for removal of large materials will cause blockage and require frequent backwashing and removal of accumulated debris.

3.1.4 Anaerobic Digester

The size of the anaerobic digester is considered appropriate. The 4 No. bioreactors have a total volume of 250 m^3 (62.5 m^3 per tank). The long design retention time of 50 days minimum allows achievement of biogas yields in excess of 90%.

The use of cement 125 mm (5 inches) thick cement blocks at the base of the bioreactor (dome) is not appropriate as it may affect the structural integrity of the bioreactor in the medium to long term. Small concrete blocks should have been used for the entire dome. The builder has given assurances that a rich mix of cement/aggregate plastering will be used in rendering. Special cement (such as corrosion resistant sulphate-cement) shall also be used for rendering the top underpart of the dome.

3.1.5 Gas Holder

The design volume of the gas holder is given as 4.6m^3. The basis for the estimation of the daily biogas generation proposed to be about 26 m^3 per day is not indicated. The Edina Essaman biomethanation plant which has a total digester design volume of 250 m^3 can generate up to 22 m^3 per day taking into consideration the type of substrate (excreta) and retention time used. This indicated generation rate may therefore be considered as the expected daily production range.

3.1.6 Gas Plant

The designer/builder has not provided specific details about the biogas cleaning process and the required accessories. It is therefore not possible to do an assessment of the workability of this component of the project. It significant to note that the project sustainability analysis as provided in the project document does not consider energy generation as one of the revenue streams for the project.

3.2 Workability of Excess Grey Water Processing Plant

The excess gray water processing plant serves the purpose of treating influent wastewater containing faecal matter to a desired quality suitable for re-use in irrigated agriculture. The design proposed by the Global Renewal Energy Services consists of 3 unit processes. The plant configuration shows flow from the hydro-segregation tank to the biological-bed filter (bio-bed) to the solar water purification tank and then to the collection tank. The proposed unit processes will achieve the following treatment objectives:

- *Settling and Upflow Filtration* – the hydro-segregation tank gravity acts as settling and upflow filtration tank (made up of 4 layers of screens and gauze). The supernatant flows to the biological-bed (bio-bed).
- *Removal of dissolved organics* – the bio-bed which consists of activated carbon, gravel and sand serves as the medium for the removal of organic compounds.
- *Disinfection* – the solar water purification tank will ensure the removal of pathogens. Solar disinfection is a naturally occurring disinfection method which does not require the application of any chemicals. Solar disinfection is classified as an advanced oxidation process (AOP).

Activated carbon adsorption will in principle ensure removal of organic matter it is typically used in practice either to remove soluble organics following chemical-physical treatment or as an advanced wastewater treatment step following conventional biological treatment.

Thus the above unit processes in principle can achieve the desired water quality under optimal conditions. However, the workability of the excess grey water processing plant can be inhibited by the following:

- *lack of pre-treatment* – there is no primary screening of the cesspit emptier contents and this can lead to obstruction of flow;
- *Choice of construction material* - all the tanks have being constructed with cement blocks. Liquid retaining tanks should be with durable materials such corrosion resistant/low permeability concrete or well-coated steel. The designer/builder will

have to provide explanation for this choice and/or remedial action to ensure durability and structural integrity.

- *Lack of treatment unit redundancy* - there are no flow by-pass system or holding tanks for faecal sludge to allow for planned maintenance or breakdown of any of the other unit processes.

3.3 Digested Residues Processing Plant

The digested residues processing plant serves the purpose of treating digestate from the anaerobic bioreactor to a desired quality suitable for re-use in irrigated agriculture. The proposed design consists of two unit processes. The proposed treatment objectives include:

- Disinfection – the solar pasteurizing tank will ensure the removal of pathogens similar to the process described for the solar water purification plant.
- Maturation – to ensure further maturation of the solid residues prior to the utilization.

Other issues of concern regarding the workability of the digested residues processing plant are as for the previous unit processes.

It is noteworthy that the project sustainability analysis does not consider the sale of digested residues as one of the revenue streams for the project.

3.4 Workability of Autonomous Water Supply System

This is intended to be a groundwater mechanized borehole with overhead tanks, fitted with stand pipes. The system is expected to yield 2,000 gallons a day. Information is not provided on construction activities related to the system such as borehole test/yield results, water treatment methods, and electro–mechanical works.

Information from the contractor indicates that the borehole will be constructed at a location not too distant from the site but which's location has not been provided. It is therefore recommended that it is sited taking into consideration the minimum buffer distance of not less than 360m.

3.5 Workability of Biogas Generating System

The design does not provided specific details about various elements of this project component; type of generator, capacity of the generator, generator operational procedures, proposed utilization and sale of biogas.

In the absence of these parameters it is not possible to do an assessment of the workability of this component of the project.

3.6 Outputs and By-Products from Biomethanation Plant

The expected outputs and by-products from the pilot biomethantion plant include the following:

- Methane gas
- Nutrient–rich liquor digestate

The daily and annual values for each of these are presented in Table 3.1. These values were obtained based on the United Nations Framework Convention on Climate Change (UNFCCC[2]) methodologies for recovery of methane from wastewater treatment systems. The detailed results are presented in Appendix B.

Methane Gas

Parameter	**Value**	**Units**
Daily Methane Production	15.7	kg/day
Annual Methane Production	5.7	tonnes/year

Solid Digestate (Cake)

Parameter	**Value**	**Units**
Daily Dry Solids Production	50.0	Kg/d
Annual Dry Solids Production	18.2	tonnes/yr

Nutrient-rich Liquor

Parameter	**Value**	**Units**
Daily Liquor Production	2.45	m^3/d
Annual Liquor Production	894	m^3/yr

Table 3.1 Outputs and by-products from biomethanation plant

[2] UNFCCC/CCNUCC Guidelines AMS-III.H Methane Recovery in Wastewater treatment,

4.0 QUALITY ASSURANCE OF CONSTRUCTION WORKS

4.1 Scope of Construction Works

The scope of construction activities for the Edina Essaman project can be grouped under the following categories:

- Construction of bio-conversion plant
- Construction of excess grey water processing plant
- Construction of digested residues processing plant
- Installation of biogas generator
- Construction of autonomous water supply system
- Auxiliary and Ancillary works

Table 4.1 presents a summary of project financing and cost schedules. At the planning stage, the entire assignment which started in April, 2013 was envisaged to end in October , 2013. Due to challenges and setbacks to projects of this nature, the construction has been re-scheduled to be completed in March 2014.

Table 4.1: Summary of Financing and Cost Schedules

Item	Description	Original	Revised Schedules	
			Previous	New 2014
1	Provisional Contract Sum	GH¢ 275,600		
2	Funding	Embassy of Kingdom Netherlands (EKN), Ghana/GoG/KEEA MA		
3	Design and Build Contractor	Global Renewable Energy Services		
5	Contract Duration	6 months	9 Months	12 Months
6	Works Contract Signed			
7	Handover of Site	28th March 2013		
8	Commencement	April 2, 2013		
8	Intended Completion	October 2, 2013	Dec. 12, 2013	Mar. 15, 2014
9	No. of Payments	3		
9.1	Payments made so far	137,872.99		

9.2	No. IPC Presented	5		
9.3	No. IPC fully honoured	3		
9.4	Amounts certified to date	137,872.99		137,872.99
10	% Elapsed Time	Over 100%		Over 100%
11	% Cumulative Progress			55%
*The progress is at 7th January 2014				

4.2 Site Organization and Construction Practices

A description of construction practices observed during the site inspection is provided in Table 4.2. Construction activities are in close proximity to the waste dump leading to interference from refuse dumping trucks. Fig 4.1 shows photographs of construction practices observed on site. A detailed photo gallery showing current progress is presented in Appendix C.

Table 4.2 Assessment of site organization and construction practices

Description	**Comments**
Site security	The site is not secured. There is easy access to this location. The site is well demarcated by boundary pillar but there are no barbed wire meshes.
Site infrastructure	There are no site offices, storage sheds or internal vehicle lanes or parking area(s)
Technical expertise of site personnel	The contractor does not have a well-qualified foreman on site (this is to be confirmed)
Occupational health and safety	There is no safety equipment on site. Workers do not have protective clothing.
Material testing	No curing tanks of concrete cubes were observed.
Plant and equipment holding	No equipment for material handling and preparation or for surveying tasks such as setting out, plumb lines was observed.
Material storage	Construction materials such aggregates, cement blocks and bricks were stored in the open.

Signboard of Biomethanation Project

Poor access road to Project Site

Inadequate site office – storage shed

Refuse disposal area

Storage of construction materials

Figure 4.1 Photographs of site organization and construction practices

4.3 Progress of Works

Table 4.3 presents a summary of progress of work for various work activities. As a quality control check, measurements of the various structures being constructed were done on the 28th of December 2014. The as-built dimensions are presented in Table 4.4. It is observed, generally, that as-built dimensions are different from those provided in the design report and the BOQ. The detailed evaluations for various activities described under the scope of works are presented in Appendix D.

Photographs of the various activities are provided in Fig 4.2 and Figure 4.3 respectively.

Table 4.3 Progress of works of various activities

Description of Activity	**Progress (%)**
Preliminaries	55%
Bioconversion Plant	77%
Excess Gray Water Processing Plant	30%
Digested Residues Processing Plant	0%
Biogas Generator	0%
Autonomous Water Supply System	0%
Associated Works	0%

Table 4.4 As-built dimensions of constructed structures

Structure	**Constructed Volume**	**Design Volume**
Hydro-segregation chamber	5.28 m^3	4.2 m^3
Bio-Bed	6.68 m^3	3.6 m^3
Solar water purification plant	6.33 m^3	5.4 m^3
Reclaimed water tank	17.02 m^3	Not specified

Bioreactor 1 – completed dome with inlet/outlet chambers

Bioreactor 2 – completed dome with inlet/outlet chambers

Bioreactor 3 – dome construction in progress

Bioreactor 4 – dome construction in progress

Hydro-Segregation tank under construction

Figure 4.2: Bioconversion plant

Biological-bed filtration

Solar water purification tank – showing baffles

Reclaimed water tank

Figure 4.3: Excess grey water processing plant

4.4 Outstanding Works and Revised Schedule

Table 4.5 presents a list of major activities that are yet to commence. The Contractor's revised work schedule for completing all outstanding works by March 15, 2014 is presented in Table 4.6 i-v (see also Appendix E).

Table 4.5 Major activities that are yet to commence

BOQ Item No.	**Description**
1B/5	Gas holder
1D/1	Solar pasteurizer
1B/6	Gas plant with compressor
1E/1	Biogas running electric generator plus housing, wiring etc.
IF/1	Autonomous water supply system
1G/1	Sewage inspection/works room
1G/2	Plumbing and engineering installations
1G/4	Electrical installations
1G/4	Painting
1G/5	External works
11	Initial operation of facility

Table 4.6 i. Revised Phase 2 Construction Schedules and Costs

BOQ Page No	Item	Description	COST (GH¢)	TIME FRAME (WEEKS FROM DATE OFPHASE 2 FUNDS RELEASE)		
				WEEK S 1,2,3,4,5 (19.08/13 – 20/09/13)	WEEKS 6,7,8,9,10) 23/09/13 – 01/11/13)	
2	1B/1	Bioreactors (2 modules with total capacity 125 m3)	43,750			
2	1B/2	Hydro-segregation chamber	9,240			
2	1B/3	Entrance chambers (2 modules @ 1.8 m3)	630			
2	1B/4	Hydraulic expansion chambers (2 modules @1.8 m3)	630			
3	1C/1	Bio-bed (3.6 m3)	3,240			
3	1C/2	Solar water purification plant (5.4 m3)	5,940			
3	1C/3	Reclaimed water tank/pump	1,660			

4	1G	External works)	1,000			
5	13	Miscellaneous items	200			
5	12	Contingencies	1,000			
		Total	67,290			

Table 4.6 ii: Revised Phase 3 Construction Schedules and Costs

BOQ Page No	Item	Description	COST (GH¢)	TIME FRAME (WEEKS FROM DATE OFPHASE 3 FUNDS RELEASE)		
				18/11/13 – 20.12/13	WEEKS 27/12/13 – 24/01/14	
2	1B/1	Bioreactors (next phase of either 2 modules with volume 62.5 m3 each or single module with volume 125 m3)	43,750			
2	1B/3	Entrance chambers (2 modules @ 1.8 m3)	630			
2	1B/4	Hydraulic expansion chamber (2 modules @ 1.8 m3)	630			
3						
4						
5	12	Contingencies	1,000			
5	13	Miscellaneous items	62			
		Total	46,072			

Table 4.6 iii: Revised Phase 4 Construction Schedules and Costs

BOQ Page No	Item	Description	COST (GH¢)	TIME FRAME (WEEKS FROM DATE OFPHASE 4 FUNDS RELEASE)		
				31/01/14 -	21/02/14	
2	1D/1	Solar pasteurizer (4.8 m3)	5,280			
2	1B/5	Gas holder (4.6 m3)	5,520			
2	1D/2	Drying beds/packaging unit	2,000			
3	1B/6	Gas plant with compressor	4,500			
4	1G	External works	300			
5	13	Miscellaneous items	100			
4	1E/1	Biogas running electric generator plus housing, wiring etc	12,000			
4	1F/1	Autonomous water supply systems	15,000			
5	12	Contingencies	400			
5		Miscellaneous items	62			
		Total	45,162			

Table 4.6 iv: Revised Phase 5 Construction Schedules and Costs

BOQ Page No	Item	Description	COST (GH¢)	TIME FRAME (WEEKS FROM DATE OFPHASE 5 FUNDS RELEASE) 24/02 – 15/03/2014
4	1G/1	Sewage inspection/Workrooms	14,000	
4	1G/2	Plumbing and engineering installations	6,500	
4	1G/3	Electrical installations	2,000	
4	1G/4	Painting	2,500	
4	1G/5	External works	200	
5	11	Initial operation of facility	4,200	
5	12	Contingencies	283	
6		Miscellaneous items	62	
		TOTAL	29,745	

Based on the progress of works achieved by the Contractor between 23rd December 2013 and 7th January 2014, all the works can be completed per the revised schedule if requests for payments are processed timeously and the contractor adheres to the schedule (see Picture Gallery of Progress in Appendix C).

5.0 PROJECT BUDGET AND DISBURSEMENTS

5.1 Bill of Quantities

The bill of quantities covering various work activities for the Edina Essaman Biomethanation Project is shown in Table 5.1. The total estimated project cost is GHC 275,600.

Table 5.1 Bill of quantities for project

Description of Activity	**Amount (GHC)**
Preliminaries	51,750
Bioconversion Plant	109,280
Excess Gray Water Processing Plant	10,850
Digested Residues Processing Plant	7,280
Biogas Generator	12,000
Autonomous Water Supply System	15,000
Associated Works	26,500
Subtotal A	**275,600**
Project Design – 15.5% of subtotal A	36,738
Project Supervision - 5% of subtotal A	8,906
Total	**268,293**
Initial operation of facility	5,200
Contingencies- 1% of total	2,683
Miscellaneous services and items	525
TOTAL PROJECT COST	**275,600**

5.2 Contractor's Requests for Payment for Completed Works

A review of project correspondence shows actual works dome as per the contractor's requests for payment on 15th May, 2013 and 5th November 2013 as presented in Table 5.2 and Table 5.3 respectively. These activities relate to mobilization and Phase 2 activities.

Table 5.2: Itemised Request for payment - 15th May 2013

Item No.	**Description of Activity**	**Claims (GHC)**
1A/1	Movement to site	3,700
1A/2	Setting out	5,300
1A/5	Site occupancy	10,700
-	Site clearance	1,150
1B/1	Anaerobic bioreactor	1,230
1B/3	Entrance chamber	170
1B/5	Hydraulic expansion chamber	170
1B/2	Hydro-segregation tank	2,632
-	Materials	1,197
1C/1	Bio-bed	1,175
-	Design services	22,080
-	Project bonds	1,850
	TOTAL	**51,335**

Table 5.3: Itemised Request for payment - 5th November 2013

Item No.	**Description of Activity**	**Total Cost (GH₵)**	**Claims (GH₵)**
1B/1	Bioreactors (2 No.)	53,750	53,750
1B/2	Hydro-segregation tank	9,250	9,250
1B/3	Entrance chamber (2 No.)	630	630
1B/5	Hydraulic expansion chamber (2 No.)	630	630
1C/1	Bo-bed	3,250	3,250
1C/2	Solar water purification plant	5,950	5,950
1C/3	Reclaimed water tank	1,660	1,660
1G	External works	1,000	200
13	Miscellaneous items	200	200
	TOTAL	**66,290**	**65,790**

5.5 Payments to Contractor

Four payments totaling GH₵ 137,872.99 have been made by the KEEA Municipal Assembly to Global Renewal Energy Systems. The dates of issue and the corresponding amounts paid are shown in Table 5.5.

Table 5.5 Payments made to Global Renewal Energy Systems

Item No.	Interim Payment Certificate No.	Amount Paid (GH₵)	Amount Requested (GH₵)
2/4/2013	No.1	40,187.55	185,000.00
9/8/2013	No.2	36,153.72	36,153.72
4/11/2013	No.3	61,531.72	90,696.00
	Total	137,872.99	

Source: KEEA Finance/ Works Departments (confirmed by Global Energy Resources Ltd)

5.6 Value for Money Assessment

Site inspections conducted on the 23rd and 28th December shows that a number of works are behind schedule or not performed satisfactorily even though payment requests have been met. Table 5.6 presents a list of such activities.

This problem has arisen because the contractor has not provided a detailed work breakdown structure and a corresponding cost schedule which enables proper valuation of progress and completed works (see Annex F for Contractor's response).

Table 5.6 List of activities which have low value-for-money

Item No.	Description of Activity	Claims (GH₵)
1A/1	Movement to site	3,700
1A/2	Setting out	5,300
1A/5	Site occupancy	10,700
1B/2	Hydro-segregation tank	9,250
1C/1	Bio-bed	3,250
1C/2	Solar water purification plant	5,950
1C/3	Reclaimed water tank	1,660
-	Design services	22,080
	TOTAL	**63,000**

6.0 Socio-Economic Benefits and Financial Viability

6.1 Socio-economic benefits

The biomethanation plant has potential benefits for handling wastewater, septage and faecal sludge currently discharged untreated into the environment. The pilot plant size of 5m^3 handles about 10% of the total estimated cesspit emptier volumes discharged daily at the dump site.

The pilot plant can generate 15.7 kg/day of biogas (methane), 50 kg of dry solids daily and 2.45 m3/d of nutrient rich liquor (see Table 3.1 above). Figure 6.1 is a simple value chain of the socio-economic benefits of the facility.

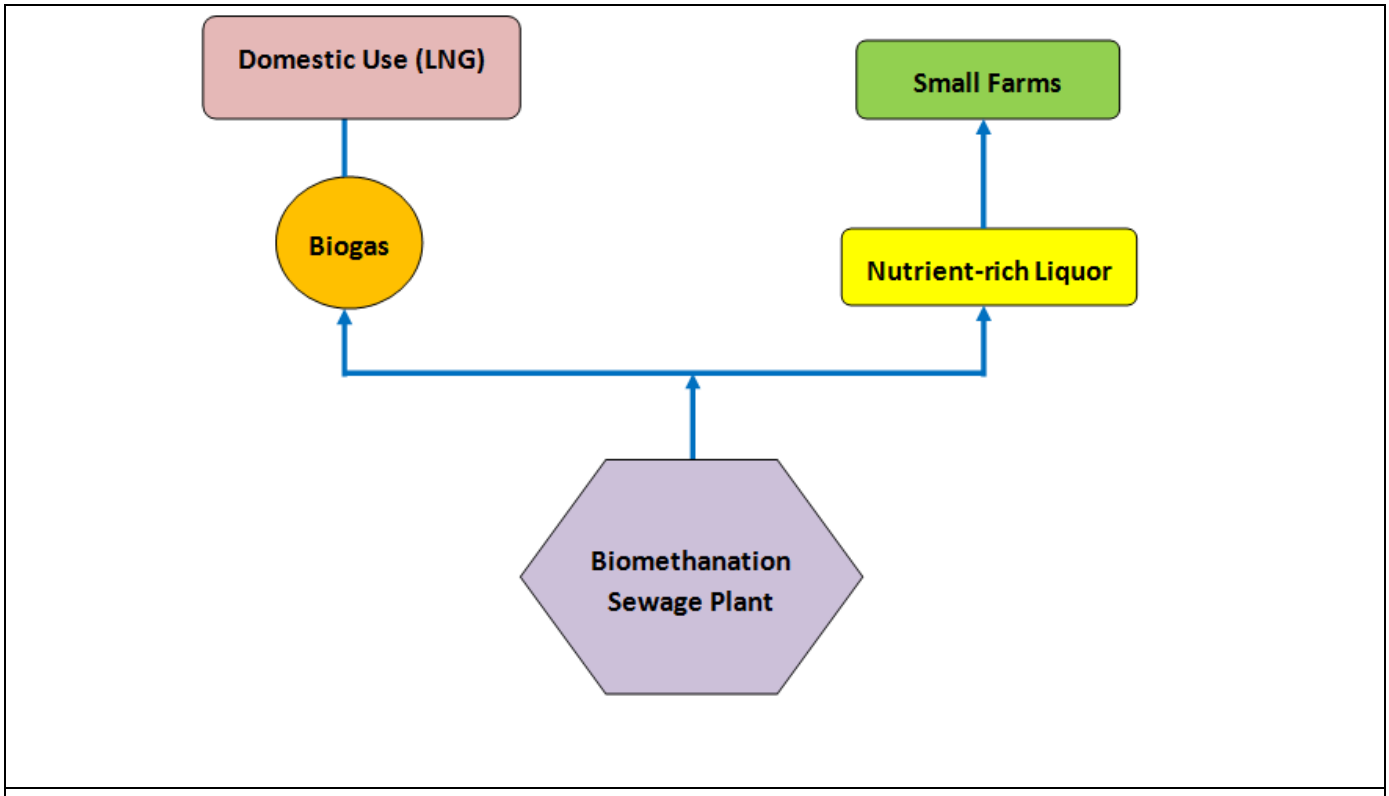
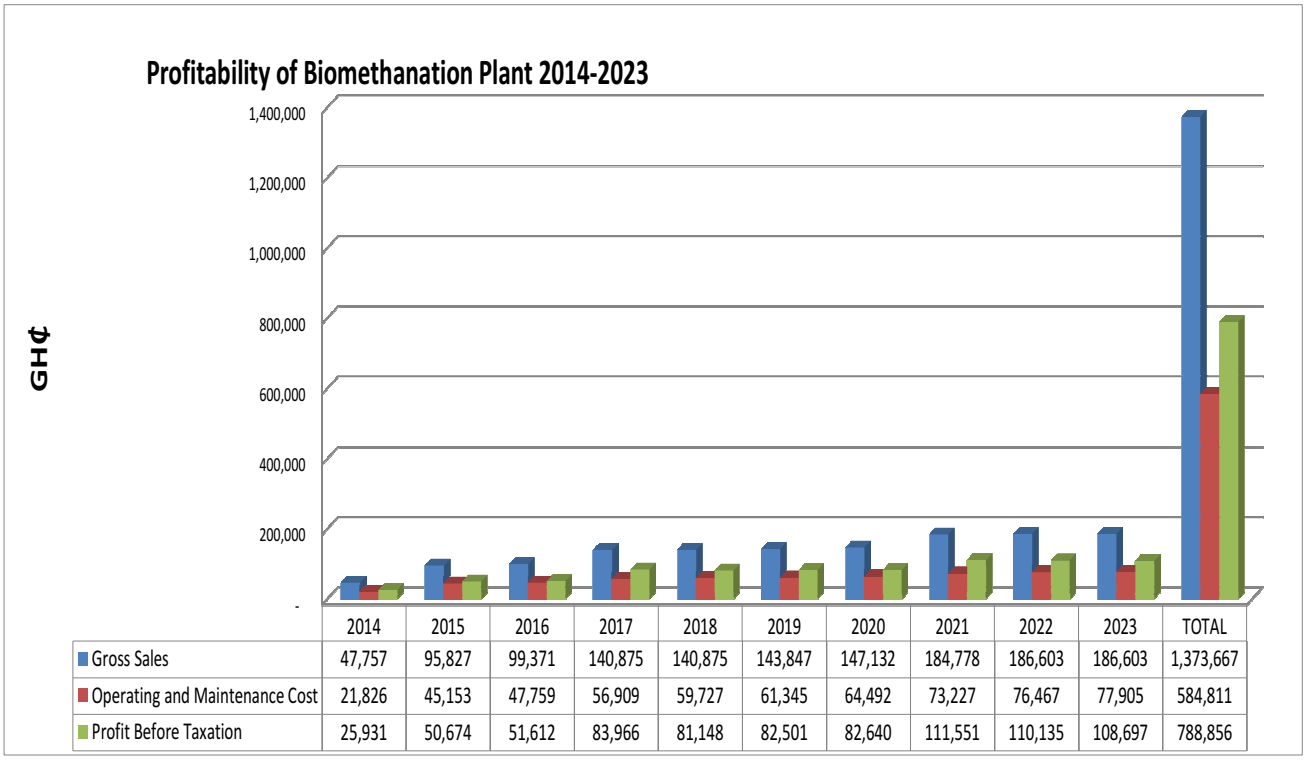


Figure ES1: Value-Chain of Biomethanation Plant



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
Gross Sales	47,757	95,827	99,371	140,875	140,875	143,847	147,132	184,778	186,603	186,603	1,373,667
Operating and Maintenance Cost	21,826	45,153	47,759	56,909	59,727	61,345	64,492	73,227	76,467	77,905	584,811
Profit Before Taxation	25,931	50,674	51,612	83,966	81,148	82,501	82,640	111,551	110,135	108,697	788,856

Figure 6.2: Profitability of 5m^3 per day Biomethanation Plant (including borehole water system)

The construction of a larger plant to handle up to 40 m^3 of faecal sludge a day has added potential for improving the value-chain of the major agricultural activities of the low-income peasant pineapple farmers in and around Edina Essaman and beyond. There is potential for producing about 2 metric tonnes of organic soil ameliorant (OSA) by mixing the produced and an organic binder (sawdust or MSW compost).

Appendix G. shows the value-chain and financial analysis of potential scenario of a larger plant. A detailed value chain analysis will reveal the comprehensive activities-output and benefits accruing to all the value-chain actors under this scenario.

6.2 Financial Viability

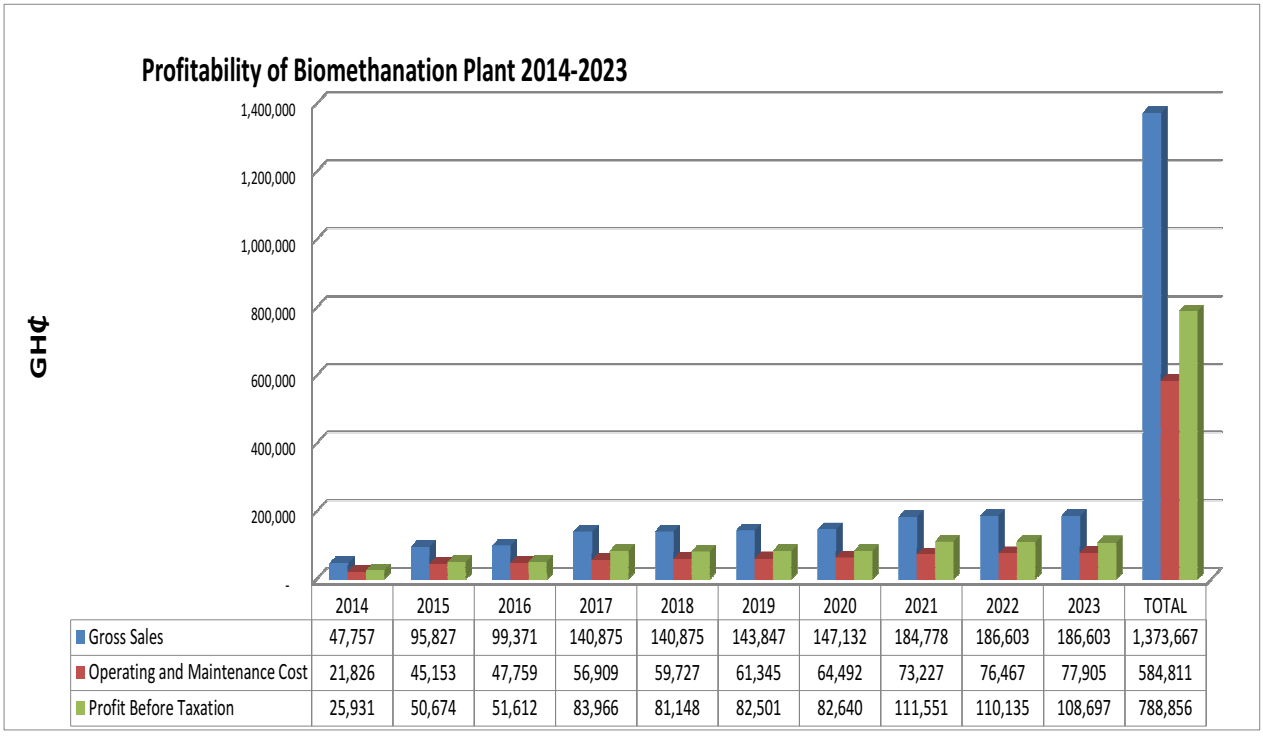
A projected financial analysis for the initial ten (10) years of operation shows that the Biomethanation plant alone cannot cover even operation and maintenance costs let alone capital investment. This is so because sales of gas as well as tipping charges will contribute about GH₵291,832 for the period as against a fixed cost of GH₵349,376.

The inclusion of the autonomous water supply system to the biomethanation plant improves the recovery of costs and profitability of the entire project.

Table 6.1 details of the contribution per by-products of the biomethanation process and water from borehole (autonomous water supply), while Figure 6.1 shows the overall profitability of the project.

Table 6.1: Product Operating Statement

	Desludging Fee	Methane Gas	Organic Soil Ameliorant	Sub Total	Water	grand total
Sales	62,525	154,637	98,505	315,667	1,058,000	1,373,667
Variable Cost	6,253	7,732	9,851	23,835	211,600	235,435
Contribution	**56,273**	**146,905**	**88,655**	**291,832**	**846,400**	**1,138,232**
Fixed Cost				349,376	240,376	349,376
Net Operating Income				**(57,544)**	**606,024**	**788,856**
Add back	Annual Amortisation Cost			109,020	15,000	124,020
Net Cash Flow				**51,476**	**621,024**	**912,876**



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
Gross Sales	47,757	95,827	99,371	140,875	140,875	143,847	147,132	184,778	186,603	186,603	1,373,667
Operating and Maintenance Cost	21,826	45,153	47,759	56,909	59,727	61,345	64,492	73,227	76,467	77,905	584,811
Profit Before Taxation	25,931	50,674	51,612	83,966	81,148	82,501	82,640	111,551	110,135	108,697	788,856

Figure 6.2: Profitability of 5m3 per day Biomethanation Plant (including borehole water system)

7.0 FACILITY O&M MANAGEMENT

To ensure sustainable operation and maintenance (O&M) management of the completed facility it is proposed that a number forward looking measures be considered.

7.1 Ownership and Organisational arrangement for facility management

Although the ownership has not been expressly spelt out the grant from the Netherlands Embassy is to the KEEA MA and therefore assumed to be the owner of the facility.

To ensure the continuous and sustainable operation and management of the facility, it is proposed that a Management Committee[3] should be implemented involving the following:

iv. The Municipal Assembly
v. The Edina Essaman community
vi. The Royal Stool of Essaman

The arrangement for asset ownership and O&M management is indicated in the Figure 7.1.

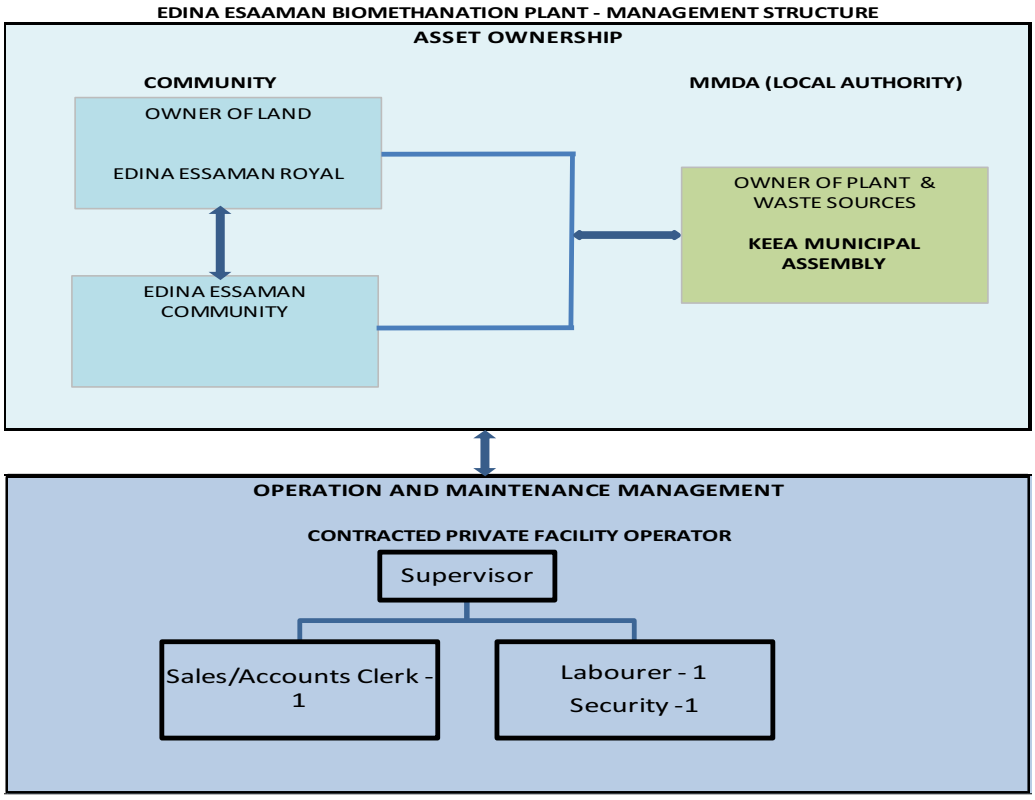


Figure 7.1: Management Structure Edina Essaman Biomethanation Plant

[3] The Management Committee can be upgraded to a Public-Private-Partnership arrangement involving a private investor if plant expansion is undertaken to receive up to 40 m3 per day of faecal sludge and secured production of organic soil ameliorant (see Annex…2)

7.2 Facility Operations and Maintenance Management

The day-to-day O&M management will be delivered by a contracted private operator. Operations management will require hiring labourers responsible for directing cesspit-emptier trucks and supervising discharging of trucks, scooping, drying and bagging the OSA. The gas will be produced and gathered automatically in a gas tank which is provided for in the construction contract.

The design of the plant is intended to minimize human intervention in the processes and maintenance. However proper design of receiving points is required if this is to be achieved. Maintenance costs will be incurred in washing and changing of screens as well as periodic hosing and cleansing of tipping points.

The proposed personnel required for O&M management of the facility is shown in Table 7.1

Table 7.1: Staff deployment for management of Biomethanation/Water Supply System

Position	**No. of Staff**
Facility Supervisor	1
Sales/Accounts Clerk	1
Labourers	1
Security Personnel	1

8.0 RECOMMENDATIONS AND CONCLUSIONS

These recommendations are based our findings, discussions of the draft assessment with stakeholders as well as responses provided by Global Renewable Energy Services Limited (the design-and-build contractor) to a number of the issues raised and observations made. The Minutes of Meetings with stakeholders and the Contractor's responses are provided in Appendices A and F to this report.

Appendices to this report are provided as a separate volume.

8.1 Technical Issues

8.1.1 Site Demarcation and Acquisition of Permits

The project site is located within the same enclosure as the dumping site which is being managed by a private operator. It is recommended that the boundaries of the biomethanation sewage plant be demarcated and fenced off before completion of the construction works. This would forestall any future conflicts with the landfill site operator or other land users with regards to use of access roads or encroachment. Additionally, the necessary site grading and drainage infrastructure should be provided at the periphery of the waste disposal site to prevent contaminated runoff from flowing to the biomethanation plant site.

8.1.2 Pre-Treatment Units

The facility should be provided with preliminary treatment units to remove large solids and grits through screening. This is particularly necessary for handling septage from cesspit emptiers. Fixtures such as coupling units for discharge hoses should be installed to ensure clean and hygienic environment at discharge points.

8.1.3 Provision of Detailed Design Documentation to KEEA MA

The contractor should as a matter of urgency provide detailed documentation including design reports and engineering drawings that provides sufficient information on all treatment system units, site infrastructure, ancillary structures, appurtenances and any other miscellaneous data that would make it possible for independent verification of all aspects of the process design and construction procedure of the treatment plant.

In particular the Contractor should provide details of the procedure for direct discharge of septage/faecal sludge directly into the biodigesters. This is critical to the hygienic and functional operation of the facility. Fixtures such as hose coupling units should be shown.

The intellectual property of the designer of propriety technology information should however be safeguarded.

8.1.4 Provision of by-pass systems

The contractor should provide flow by-passes consisting of chambers and valves to the digesters to allow for planned maintenance. It should be noted that this arrangement does not cater for redundancy of any of the follow-up unit processes such as the solar pasteurizer and drying bed.

8.1.5 Siting of Autonomous Water Supply System

In siting the borehole for the water supply system, KEEA MA and the contractor should adhere to the stipulated Ghana EPA guideline that requires a minimum buffer distance of 360 m from a waste disposal facility.

8.2 Quality Assurance of Construction Works

8.2.1 Construction Supervision of Outstanding Works

Remedial action on site organization and construction practices should be carried out to rectify the observations in Table 4.2 under Section 4. In addition the services of a short-term technical expert to assist the KEEA MA in the supervision of the final stages of the construction and test running of the Biomethanation plant will be required.

8.2.2 Completion of Works According to Revised Work Schedule

KEEA MA and the Contractor should institute a bi-monthly site meetings to review progress of works and ensure that interim certificates are issued on a regular basis and payments made promptly to meet the completion date of 15th March 2014.

8.3 Socio-Economic and Financial Viability

8.3.1 Integration of Biomethanation Plant and Water Supply System

From the financial analysis of the project, operating the Biomethanation plant in isolation of the autonomous water supply system will place additional financial burden on the KEEA MA. To secure the socio-economic benefits of the project it is recommended that both the Biomethanation and Water supply system are considered as an integrated project.

8.3.2 Scaling up of the Biomethanation Plant

The pilot plant's capacity of 5 m^3 per day which still leaves close to 90% of the municipality's untreated septage and faecal sludge being discharged directly into the environment. It is therefore recommended that a scaled-up project be considered based on the successful test-run of the pilot plant. A scaled-up plant will also potentially secure more socio-economic benefits.

8.4 Operation and Maintenance Management of the Plant

8.4.1 Clarification of Ownership of Project

As discussed during the meeting of 7th January 2014, the issue of ownership is a source of potential disagreement among key stakeholders (See Appendix A). It is recommended that the sector ministry (The Ministry of Local Government and Rural Development) and the project funding entity (Embassy of the Kingdom of the Netherlands) deliberate and communicate the ownership of the project to all interested parties.

8.4.2 Organisational Arrangement for O&M Management

It is recommended that the day-day O&M management of the plant be provided by a private contractor. A management committee comprising all key stakeholders (see Figure 7.1) should be formed to oversee the operations of the facility operator.

8.5 CONCLUSIONS

The implementation of the above recommendations will contribute to the successful completion of outstanding works. The proposed O&M arrangements if adopted will enhance sustainable operations of the facility leading the realization of the environmental and socio-economic benefits of the project.

The EKN and the Government of Ghana/MLGRD should continue to support the project to be completed, commissioned and test-run. This will provide the basis for further assessment of the effectiveness of biomethanation process and the viability of the integrated project model.