Ghanergize Power GHANA WASTE

New Integrated Waste Management Energy Plants
Zero Waste to Landfill and Zero Emissions
&
Bioreactor Landfill sites with electricity production

PENNGATE report on Waste Management, Funding, Short term, Medium & Long term Strategy

Report Author: Alan Brewer MSc. GradMCIWM - PSECC Ltd & PENNGATE Ltd January 2018

'I promise to build a Ghana that works and gives each and every one of us the opportunity to improve our lives... we are determined to forge a new Ghanaian and African, who is neither a victim nor a pawn of the world economic order, but who will be a dignified member of a successful, thriving, prosperous society.'

President of the Republic of Ghana,
H.E. Nana Addo Dankwa Akufo-Addo

Waste & Sanitation Project overview

PROJECT No. 2 – Solid Waste Management

PROJECT BACKGROUND

Solid waste management in urban areas in the country is a major problem. This problem can be handled through the provision of adequate solid waste infrastructure, good attitudinal changes and strict enforcement of the various MMDAs sanitation byelaws. Since most of the regional capitals have engineered landfill sites, the remaining ones if provided, would help them manage their solid waste to avoid accumulation of refuse at unauthorized dumpsites in these regional capitals. The targeted regional capitals, which do have landfill sites and would benefit the project, are Sunyani, Wa and Bolgatanga and Koforidua. The Solid Waste Management Improvement Project for the four-targeted regional capitals in the country will provide the following:

- Construction of four (4) landfill sites in Sunyani, Wa, Bolgatanga and Koforidua
- Construction of two (2) transfer stations each in Sunyani, Wa, Bolgatanga and Koforidua

PROJECT OBJECTIVE

The project objectives are:

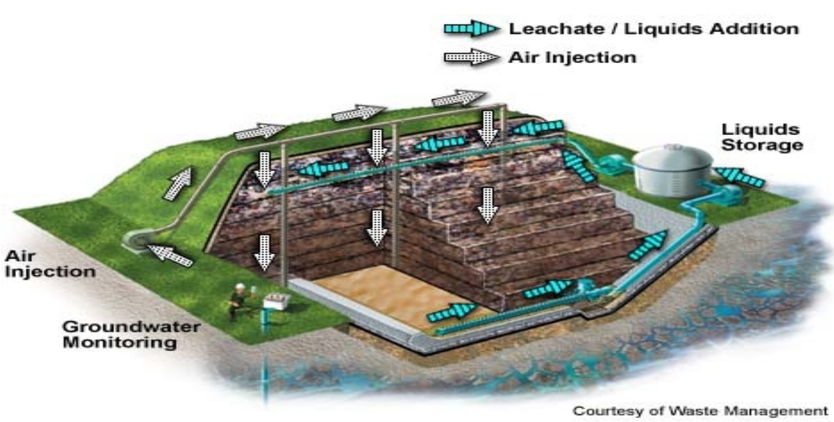
- To improve solid waste management in four regional capitals through provision of infrastructure.

EXPECTED OUTCOME

- Four engineered landfill sites constructed in Sunyani, Wa, Bolgatanga and Koforidua
- Eight transfer stations provided in Sunyani, Wa, Bolgatanga and Koforidua
- 3 mini transfer stations in Ashiaman, Tema and Pokuase

REMARKS

The construction of these landfill sites and transfer station in these regional capitals will improve solid waste management to promote cleanliness and public health.



New Energy Plants, New initial Bioreactor Landfill sites with electricity production.

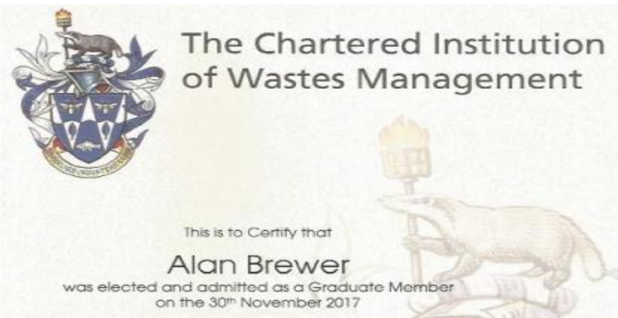
The landfill will probably be self- financing by the time you are ready to open the WTE plant

PENNGATE

Forward - Solid Waste Management (SWM) has become one of the crucial parameters of Urbanization. One New Energy Plant and one New Bioreactor Landfill site could deal with all of ACCRA's Waste. Ghana has recognized its importance and is establishing its Waste Strategy, this could include a short Term, Medium to Long Term approach dealing with the Wastes problems in Ghana together with protecting Environmental concerns. ACCRA generates 2,000 metric tonnes of waste a day and urgent measures have been adopted to deal sustainably with this waste. The time has come to move forward and PENNGATE will provide both technology providers, funding partners and will emphasize all the different aspects of SWM through proper assessment and providing appropriate solutions. Scientific understanding is key to achieve success in this field. Many studies have been done on waste eminating in Ghana - PENNGATE have the solution to assist Ghana reaching Sustainable Waste, infrastucture and Strategy.

We need to focus down on waste from Kumasi & ACCRA first to make a good statement for good Waste Management in Ghana. Previously, the four landfill sites indicated in this Project No. 2 were a possible solution and not set as a definitive plan, then, in view of the fifteen Waste Transfer stations currently in ACCRA and those in Kumasi we should utilise that waste as a feedstock to our New Energy Plants & New initial Bioreactor Landfill sites with electricity production. We also should close the Oblogo landfill sites and cap it and then have another new Bioreactor landfill site close to ACCRA & Kumasi where waste in Transfer Stations can be stored and electricity produced. We can of course add two of the other landfill sites from the list in the original brief if required as a choice for the Government. PENNGATE further propose another three New Energy Plants over the next five years funded via PENNGATE. All of ACCRA 's waste, as an example can be treated in one Energy Plant and one Bioreactor landfill site, the first Energy Plant opperational after two years.

The publication "Municipal Solid Waste Management (MSW) in Developing Countries" such as Ghana has been utilised in this report, all aspects of MSW are covered, It provides the basic guidelines to achieve Sustainable Municipal Solid Waste Management (SMSWM) in Ghana over time. The relevance and knowledge in managing MSW is explained and a Strategic programme identified for Ghana to follow in the Short Term, Medium and Long Term to achieve Sustainable Waste Management. The protection of the environment and future generations are paramount.


The Chartered Institution of Wastes Management

This is to Certify that

Alan Brewer

was elected and admitted as a Graduate Member on the 30th November 2017

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Energy Plants for all waste types, ZERO Emissions, ZERO to Landfill, Electricity production and some seperation of glass and metals - this is a Sustainable approach for Ghana.

Report by Alan Brewer MSc. GradMCIWM PSECC Ltd for PENNGATE Ltd

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1. Executive Summary

Ghana produces 5.054 tonnes of waste each year - Accra generates over 2,000 metric tonnes of waste (MSW) a day or 730,000 tonnes per annum (tpa) and urgent measures need to be adopted to deal sustainably with this waste. PENNGATE propose a new funded Bioreactor Landfill site and one New Energy Plant in ACCRA that will deal with all ACCRA's Waste (MSW), For this initial project, PENNGATE have made funding provision possible to provide finance $315 million for the New Bioreactor Landfill site for Kumasi / ACCRA and Energy Plant producing electricity from waste.

Waste is as a valuable resource and can help lead the way forward to a 'successful thriving and prosperous society' for Ghana. An International Team study was performed in Ghana in 2015 indicating waste generation per person with an average of 0.47 kg per person per day amounting to 5.054 million tonnes per year with a growth rate of 2.18% per year. General waste regulations and hazardous waste regulations exist and a Policy framework that guides the management of hazardous, solid and radioactive wastes in the Country. This is embodied in the Local Government Act (1994), Act 462 and the Environmental Sanitation Policy (ESP) of 1999. In 2018 the Government of Ghana wish to embark upon an ambitious Waste Management programme and could enhance current waste practices even further. The new Government propose, in the short term, four initial landfill sites at Sunyani, Wa, Bolgatanga and Konoridua and two Transfer Stations at each landfill site. Kumasi is another City requireing assistance with Waste management. All of ACCRA's waste can be treated in one Energy Plant and one Bioreactor landfill site. PENNGATE propose that, in the medium term could see improved collection, transfer and the New Integrated Waste Management Plants Waste with Energy Plants operational producing electricity from Gasification of Waste, a Renewable Energy source. It is possible to do this within two years. We need to focus down on waste from Kumasi and ACCRA first to make a good statement for good Waste Management in Ghana. Previously, the four landfill sites indicated in this Project No. 2 were a possible solution and not set as a definitive plan, then all these sites should have New Boreactor Landfill, also the New Energy plants. Aforability ia an important issue the Energy Plants and Bioreactor could be a key driving forces. In considering the fifteen waste Transfer stations currently in ACCRA we should utilise that waste as a feedstock to New Energy Plant. We also should close the Oblogo landfill site and cap it then site another new landfill site close to ACCRA where waste from ACCRA Transfer Stations can be stored. We can of course add two other landfill sites from the list in the Governments origional brief.PENNGATE further propose another three New Energy Plants over the next five years. if required as a choice for the Government with Zero new waste going to Landfill with Zero emissions and Revenue generation over a twenty-five-year period. Progress is being made to achieve these targets, PENNGATE will make these landfill sites Bioreactors for two years producing electricity then the waste could be used as a feedstock to the New Energy Plant producing electricity. Kumasi should also be considered for a Bioreactor and Energy Plant.

Waste management contractors are emerging in Ghana with improving experience. These are limited to collection and transportation companies serving Metropolitan areas. The largest and best equipped appears to be ZoomLion. PENNGATE's management approach of MSW for Ghana is to work with ZoomLion to enhance street collection, transfer and to have after two years Zero waste to landfill by the adoption of the New Energy Plants. PENNGATE further recommend closure, on health and environmental grounds of the the Oblogo landfill site and cap it and then construct immediately another new Bioreator Landfill site close to ACCRA where waste from the Transfer Stations can be stored. We can of course add two of the other Landfill sites such as Sekondi-Takoradi or from the list from the Governments original brief if required as a choice for the Government. with Zero new waste going to Landfill with Zero emissions and Revenue generation over a 25 year period. Transfer Stations will cost $350,000 each & BioreactorsLandfill $8.96 million.

New Energy Plants will help provide funding towards Ghana's Waste Strategy objectives over the next twenty. Years. The landfill will probably be self- financing by the time you are ready to open the WTEnerggy plant.

The new Bioreactor Landfill is an initial requirement until the Energy Plant is operational.The long-term could see further Bioreactor Landfill sites, Landfill recovery of materials and the introduction of Material Recovery Facility (MRFś) and more Integrated Waste Management Plants where some of the plastic, all the glass and metals are separated out of the MSW and new manufactured goods made, also electricity production from Gasification from the energy plant technology. This approach will mean Sustainable Waste Management, job creation, manufacturing enhancement in Ghana and extra revenue generation all from products that has previously been viewed as waste. As indicated, one of the roles of the EPA is to prescribe standards and guidelines concerning the discharge of wastes and control of toxic substances. To date three relevant guideline documents have been published:

- Ghana Landfill Guidelines May 2002 Guidelines for the Management of Healthcare and Veterinary Waste in Ghana 2002 and •
- Best Practice Environmental Guidelines Series No 3 –Manual for the Preparation of District
- Waste Management Plans in Ghana, July 2002.

The Ghana Landfill Guidelines published by the EPA were an attempt to promote the phased upgrading of landfills, initially by improving site selection waste compaction and drainage resulting in High Density erobic Landfills' (target was for all Metropolitan, Municipal and Large Urban landfills by 2010) and culminating in achieving operation of Sanitary Landfills'by 2020 (again for larger landfills). Ghana is a signatory to the MARPOL Convention (Marine Pollution Convention), although not all parts are ratified yet, and as such is expected to have facilities for the reception of M RPOL wastes'which include oily wastes and refuse (and sewage when this part is ratified). Ghana currently has limited facilities capable of managing MARPOL wastes although Takoradi port has access to a good standard facility for oily wastes. These waste can be processed in our New Energy Plants.

Energy Plants for all waste types and with some separation of wastes such as glass and metals - this is a Sustainable approach for ACCRA

Capital Costs		
Plant & Equipment		284,375,000
Contract, Legal, EIA Etc		5,000,000
Working Capital		6,000,000
SubTotal		**295,375,000**
Placement Fee	1%	2,953,750
Sales	6%	17,062,500
Sub Total Other costs		31,016,250
Total CAPEX		315,391,250
Capital Structure		
Equity amount	0%	0
Debt amount	100%	315,391,250

OHEAD/Yr	15,764,101		OHEAD %
OHEAD/Project 18mths	23,646,151	284,375,000	8.32%

CAPEX $315,391,250

Energy Plants for all waste types, ZERO Emissions, ZERO to Landfill, Electricity production and some seperation of glass and metals - this is a Sustainable approach for Ghana.

Energy Plant is 35MW in size generating 840 MWh per day or 380,190 MWh per year.

Ghana has also acceded to the Basel Convention on transboundary movement of hazardous waste, which implements controls on the movement of hazardous (and certain other) wastes into or between signatory countries. Under the Basel Convention, transboundary movements of hazardous wastes or other prescribed wastes can take place only upon prior written notification by the State of export to the competent authorities of the States of import and each state of transit. Each shipment of hazardous or other prescribed waste must be accompanied by a movement document from the point at which a transboundary movement begins to the point of disposal. Transboundary movements are generally approved, if

(a) the state of export does not have the capability of managing or disposing of the waste in an environmentally sound manner; and

(b) the receiving state has appropriate, environmentally sound facilities, and agrees to accept the waste.

Ghana acceded to the Basel Convention on 30 May 2003 (accession has the same legal effect as ratification) which means that it must comply with all the requirements of the Convention. Therefore, certain wastes generated in Ghana, or within its territorial waters, that are exported to another country, will be subject to the provisions of the Basel Convention. Once more these wastes can be processed in the PENNGATE New Energy Plants. Waste management treatment and disposal infrastructure is currently underdeveloped in Ghana; for example, landfills are still at the stage of municipal dumps rather than sanitary or ‘engineered’ landfills This is the situation in the Western Region. Whilst these facilities are principally intended for the collection and management of general solid wastes from domestic sources, general solid wastes from commercial and industrial sources are also disposed of at these facilities. Such facilities are therefore generally available for non-hazardous general solid wastes generated by oil and gas companies operating in Ghana (although the planning manual referenced specifies that this is acceptable only if they have been ‘previously identified and quantified by the ssembly for handling’)

The New Government in Ghana have identified the need for four new Landfill sites at Sunyani, Wa, Bolgatanga and Konoridua and two Transfer Stations at each landfill site. PENNGATE propose that the Landfill sites are a temporary measure for the first two years and then all wastes will be diverted into the Medium / Long Term Energy Plants and Integrated Waste Management Plants.

The Sekondi-Takoradi Metropolitan Assembly (STMA) is negotiating to reactivate a project with World Bank funding and a company is currently re-finalising the design of the landfill site at Sekondi-Takoradi. PENNGATE would advise to contunue this project and to make this a Bioreactor solution over the next two years and then an Energy plant could be sited at this site in the future to take the existing waste as a RDF feed-stock to the Energy Plants.

PENNGATE propose to have the four Bioreactor landfill sites BUT also to utilise the MSW waste from Ghana in New Energy plants. The first plant is for Kumasi or ACCRA and sited at the existing Landfill site. After the Energy plant is operational over the next two years the waste deposited in the four landfill sites can then also be utilised in the Energy Plant. Once Ghana is underway with their Sustainable Waste Strategy then Material Recovery Facilities may also be constructed to recover and reuse waste for manufactured goods in the future. The collection of such waste and recyclables now requires the support of the Material Recovery Facility, which also has an Energy Plant attached. Manufactured goods can then be made, and new items sold with revenue gain and enhanced environmental protection occurs due to material being recycled –(Life Cycle Analysis or LCA explains this). The four Bioreactor Landfill sites in this programme together with existing Landfill sites can possibly be cleared and the resources within the Landfill such as Organics, Plastics, Metals etc can then be recycled and RDF produced as a feedstock to the Integrated Waste Management Plants.

Zero Waste to Landfill

PENNGATE propose to assist Ghana to utilise the MSW waste from Ghana with both Technology and $315 million Funding provision for the New Energy Plant, one New Bioreactor Landfill site at ACCRA and over time Integrated Waste Management Plants. The first Energy Plant is Kumasi or forACCRA and sited at the New Bioreactor Landfill site.

This will mean that 'High Density Aerobic Large Bioreactor landfills" by 2019 and culminating in achieving operation of 'Sanitary Landfills' by 2020 may not be a requirement if the Energy Plants are adopted in Ghana. Due to increase costs ofEnergy Plants it may be possible to have both Landfill, Energy Plants and Material Recovery Facilities (MRF's) over time and this is investigated here in the report. PENNGATE propose to close Oblogo Landfill site and replace with a new engineered Bioreactor Landfill.

A sanitary, lined, Landfill funded by the World Bank was planned for Sekondi- Takoradi (with 10 cells and enough capacity for approximately 15 years of waste arisings) and development commenced but the project ceased, and construction was never completed. This project should be targetted for a New Bioreactor Landfills & Energy Plants.

Short Term – Close Oblogo Landfill

Kumasi & ACCRA sites for New lined Bioreactors Landfill and then Sunyani, Wa, Bolgatanga and Konoridua

Medium Term - Energy Plants

Medium to Long Term – Energy Plants & MRF's

There are no dedicated facilities for industrial solid waste management or hazardous waste management other than basic oil water separation facilities. Our New Energy Plant can deal with this waste. Industrial solid wastes are generally disposed of in municipal dumps with or without any form of pre-treatment. There is also believed to be widespread illegal dumping. **The 730,000 tpa of waste from ACCRA could be processed by the Energy Plant and New Bioreactor Landfill site producing electricity with Zero Emissions and Zero waste to Landfill in the future.**

This report covers all aspects of MSWM, the various component systems, such as collection, transportation, processing and disposal, and their integration. Further detailed information is contained within the Appendices that offer a complete understanding of MSW and how to lead onto a Sustainable Waste Strategy in Ghana over the next four years and beyond. Various component technologies are available for the treatment, processing and disposal of MSW. As mentioned in this report, a successful Municipal Solid Waste Management (MSWM) system is the result of proper planning, funding and strategy together with the will to succeed. A very useful publication utilised has been

'Municipal Solid Waste Management (MSW) in Developing Countries" such as Ghana, all aspects of MSW are covered in this report. It provides the basic guidelines to achieve Sustainable Municipal Solid Waste Management (SMSWM) in Ghana over time. The relevance and knowledge in managing MSW is explained and a Strategic programme identified for Ghana to follow in the Short Term, Medium and Long Term to achieve Sustainable Waste Management. Short-Term –Four Temporary Landfill sites - PENNGATE propose closing the Oblogo Landfill site, cap it and develop a New Engineered Biorecator Landfill site for ACCRA & Kumasi to hold waste for the new Energy Plant.

Impact of Improper Municipal Solid Waste Landfilling

Short-Term Impacts	Long-Term Impacts
Noise, flies, odor, air pollution, unsightliness, and windblown litter. Such nuisances are generally associated with waste disposal.	Pollution of the water regime and landfill gas generation.

This new programme. If adopted could be one that takes the current Waste Management collection and disposal system in Ghana into a forward-thinking Sustainable Integrated Waste Management Strategy approach. This will include over the next two years a Zero waste to Landfill Gasification process by the adoption of New Integrated Waste Management Plants that produce electricity, Renewable Energy. PENNGATE will ensure that this is done in the most cost-effective manner utilising the Best Practice waste technology with the provision of full funding packages leading to Revenue generation. Findings from existing studies produced by the Chartered Institute of Waste Management in the UK – "making waste work toolkit" & Energy from Waste – Material Recovery Facilities (MRF's), UNEP Waste advice, Municipal Solid Waste Management in Developing Countries by Sunil Kumar (Peer Reviewed) and waste management reports produced by Tullow Ghana Limited, all have been utilised within this report. We have quantified the MSW tonnage per year of 5.054 million, we also understand the waste characteristics of that waste and propose Short Term, Medium and Long-Term Waste Strategies and Technologies.

Recommendations are made within the report from improving planning, collection, transfer of waste and It is necessary to consider the current waste management options for Ghana. It is important to understand costs and possible budget arrangements when developing waste management plans and procedures and therefore this report identifies the current situation and identifies key waste management issues. It goes onto consider the options open to Ghana and describes its current strategy for addressing these issues. Within the report there are further details describing waste management to reduce its potential adverse impact in Ghana by the introduction of Integrated Waste Management Plants with Energy from Waste (EFW) from Gasification. There will be initial requirements for Bioreactor Landfill sites, but these sites will only be operational over ten years and then the Municipal Solid Waste (MSW) can slowly be diverted into the Integrated Plants for sorting, Reuse, Recycling of Glass & metals, shredding for production of Refuse Derived Fuel (RDF) pellets as a feedstock into the Gasification plant to produce electricity. This electricity will be a Renewable Energy source and will help meet the new Targets set by this New Forward-thinking Government in Ghana. These new measures must not just be short term but Sustainable for future generations.

Oblogo - Close old Landfill site

ACCRA - New Bioreactor Landfill site

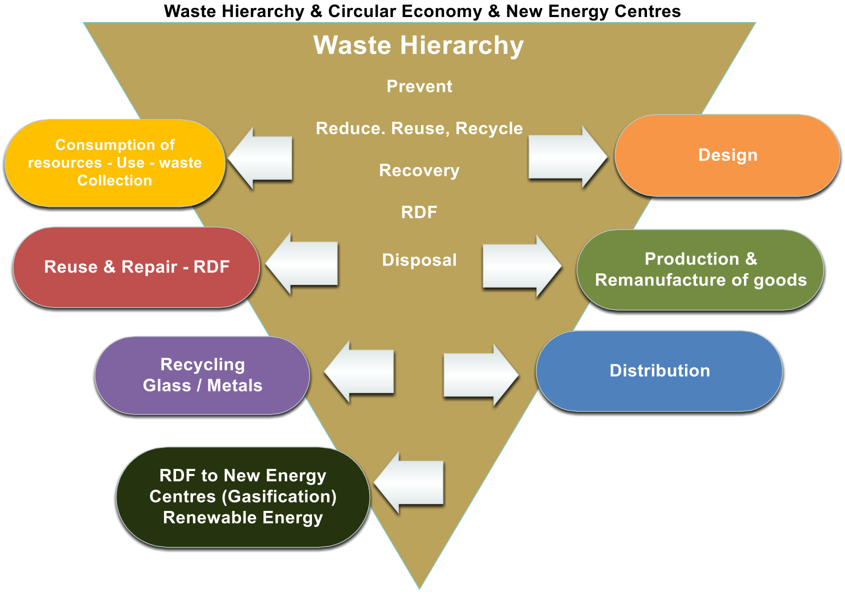
ACCRA - New Energy Plant

Major urbanisation in major Cities in Ghana puts immense pressure on the existing infrastructure facilities, among which one sector is Municipal Solid Waste Management (MSWM). There is a need to develop existing infrastructures, within Government budgets being set to make them adequate to deal with the increasing MSW tonnage per year. A good understanding of the current waste produced each year is an initial requirement and then good planning, Waste Strategy formulation and implementation together with Project Management is required.

To take forward the new PENNGATE proposals it remains important to make funding available and PENNGATE & PSECC Ltd are able to provide a funding package for the first Bioreactor Landfill and Energy plant costing approximately $315 million. The Ghana Government have set a Power Purchase Agreement (PPA) at $185 per MWh to construct the first Energy from Waste (EFW) plant and to develop a good National Waste collection service for the 5.054 million tonnes per year of MSW. Treatment, recycling, reuse, recovery of resources is important such as glass and metals and to have a good knowledge of waste Treatment technology available to Ghana to progress forward in a more Sustainable manner. PENNGATE will assist and propose Developing a new Sustainable Waste Strategy and development programme in the most cost-effective manner will require funding, good planning and design of Integrated Waste Management Plants Waste Manage and all aspects of technical, Political, environmental, legal, cultural and socioeconomic aspect considerations

Waste Management Hierarchy - Long Term appoach

Waste Hierarchy & Circular Economy & New Energy Centres



Waste going to landfill now minimized or ZERO - Sustainable

With reference to the origional brief of four engineered Landfill sites constructed in Sunyani, Wa, Bolgatanga and Koforidua and eight transfer stations with three mini transfer stations at Ashiaman, Tema and pokuase. PENNGATE are initially proposing that in the short term the Landfill sites should be constructed on a Bioreactor Landfill basis producing electricity and then over time lager Energy Plants with Zero Emission and Zero waste to Landfill to promote cleanliness and public health.constructed. The construction of the new Bioreactor Landfill sites and Transfer stations in the regional capitals will improve solid waste management (SWM).

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PENNGATE propose that the first Bioreactor Landfill should be at Kumasi or ACCRA the Countries Capital City and also construct a New Energy Plant which in time will mean No Landfill" requirement. Following this first site at ACCRA then the Energy Plant can be constructed at Sunyani, Wa, Bolgatanga and Koforidua.

WASTE MANAGEMENT INFRASTRUCTURE - ACCRA as we have seen produces 2,000 tonnes of waste per day with waste collection and transportation and disposal being very important when developing Sustainable Waste Management. There are many companies in Ghana collecting and transporting domestic-type solid wastes. The largest of these is ZoomLion which has many collection vehicles ranging from tricycles to 40m container trucks and compacting waste collection trucks. There are rudimentary capabilities for collection and transportation of liquid and hazardous wastes and need to be enhanced over time, New Energy Plants can deal with this waste in ACCRA, Waste management treatment and disposal infrastructure is currently underdeveloped in Ghana; for example, landfills are still at the stage of municipal dumps rather than sanitary or 'engineered' landfills Whilst these facilities are principally intended for the collection and management of general solid wastes from domestic sources, general solid wastes from commercial and industrial sources are also disposed of at these facilities. Such facilities are therefore generally available for non-hazardous general solid wastes generated by oil and gas companies operating in Ghana (although the planning manual referenced specifies that this is acceptable only if they have been 'previously identified and quantified by the ssembly for handling') . The total urban population in ACCRA is 2.27 million and Kumasi population is 1,370,270.

PENNGATE are proposing a new approach to waste management and treatment in Ghana, New Energy Plants with Zero emissions, New Bioreator Landfill's and in time, no need for Landfill sites. The old Landfill sites can see possible material recovery for manufacturing of goods in time. This means Job creation, revenue generation, environmentalprotection and manufacturing

The existing landfill sites in Accra are reaching full capacity and the acquisition of land for the construction of Landfill sites has become very difficult due to rapid developmental activities in Accra. However, with the current rate of development which will cause the construction of Landfill sites to be far from the source of generation, there is urgent need to get an intermediate facility, that is, waste transfer station where waste would be processed and compacted in long distance trucks to reduce the cost of waste transport and disposal.

Cost breakdown of the New Energy Plant - Integrated Waste Management

For these calculations we assume that a plant takes in 620 MT/day of MSW to produce the required 500 MT/day of RDF we remove the Metal, Glass, Stone and excess moisture if any from the incoming waste to produce the required 500 MT/day of RDF. This 500 MT/day with an average calorific value of 4,000 Kcal/kg will produce circa 32 Mwh per hour or 768 Mwh per day, also the average value for the metal, glass and stone will be after processing and commission paying in the region of US$ 20/- per ton sold at the gate. The 25 MT of Basalt type sand or gravel has no specific value so is set at US$ 5/- per ton at the gate. Carbon credits and methane credits have not been considered in this matrix.

Whilst we require a rate of US$ 185/- per plant for single or double plants, we require a slightly lower figure for multiple plants,

No.	Element and weight	Calculations	Contribution to PPA in US$
1	Metal, Stone and Glass	Here we assume that in any 620 MT/per day of MSW we get approximately 100 MT per day of Metal Glass and Stone 100 x 20 / 768 =	2.60
2	RDF	500 MT per day, 95% Organic, produced 32 Mwh per hour or 768 Mwh per day	85.36
3	Basalt type sand or Gravel	Production of average 25 MT/day at US$ 5/- = US$ 125/- per day	0.17
4	MSW not going to Landfill	620 MT/day of MSW not going to landfill at US$ 120/Mt US$ 74,400/- per day, this is an average world figure calculated for the proper construction of sanitized landfills to the accepted international standards with operation and monitoring costs of the landfill for its 30 year life. But is does not include End Of Life disposal Costs, because as of not this has not been considered but it will be high.	96.87
		Combined total cost of PPA including Zero Landfill and Electric Cost	**185.00**

NOTE :- Even if Ghana could manage to construct proper Sanitized Landfills at three quarters of the cost that it costs the rest of the world it would increase the Electric cost from US$ 85.36 per Mwh to US$ 109.58.10 per Mwh which lower than the Government is paying now for electricity, the only difference being is that our electricity is Green, Clean fully sustainable does not pollute the atmosphere and gains both Methane credits and Carbon Credits.

David J, Burton 29th November 2017

The final product:

The objective of the eradication programme is to remove all landfill waste materials from the existing dump sites, and to process and reuse as much as is possible from the dump site, and sanitise the remaining items for further use as a hard core type backfill material within the dump site reclamation process, or for the construction industry to utilise.

The main items to be recovered will form the basis for the refuse derived fuel (RDF) that can be recovered from the sites.

Until NCE are able to analysis the MSW and other waste products on the dump site, they are unable to properly assess the kcal/kg energy levels of the final RDF product to fully assess the business case of the project.

The main materials and items to be separate and segregated include:

- Bio Mass
- Plastics
- Paper
- Textiles
- Clothing
- Sand
- Earth
- Rocks and Stones
- Building Materials
- Metals
- Glass and Ceramics
- Industrial Hazardous Materials

Of the above items, the following items would be converted into RDF for the UHTH Technology Conversion Process:

- Bio Mass
- Wood
- Plastics
- Paper
- Rubber
- Vehicle Tires
- Textiles
- Clothing
- Industrial Hazardous Materials

2. Introduction

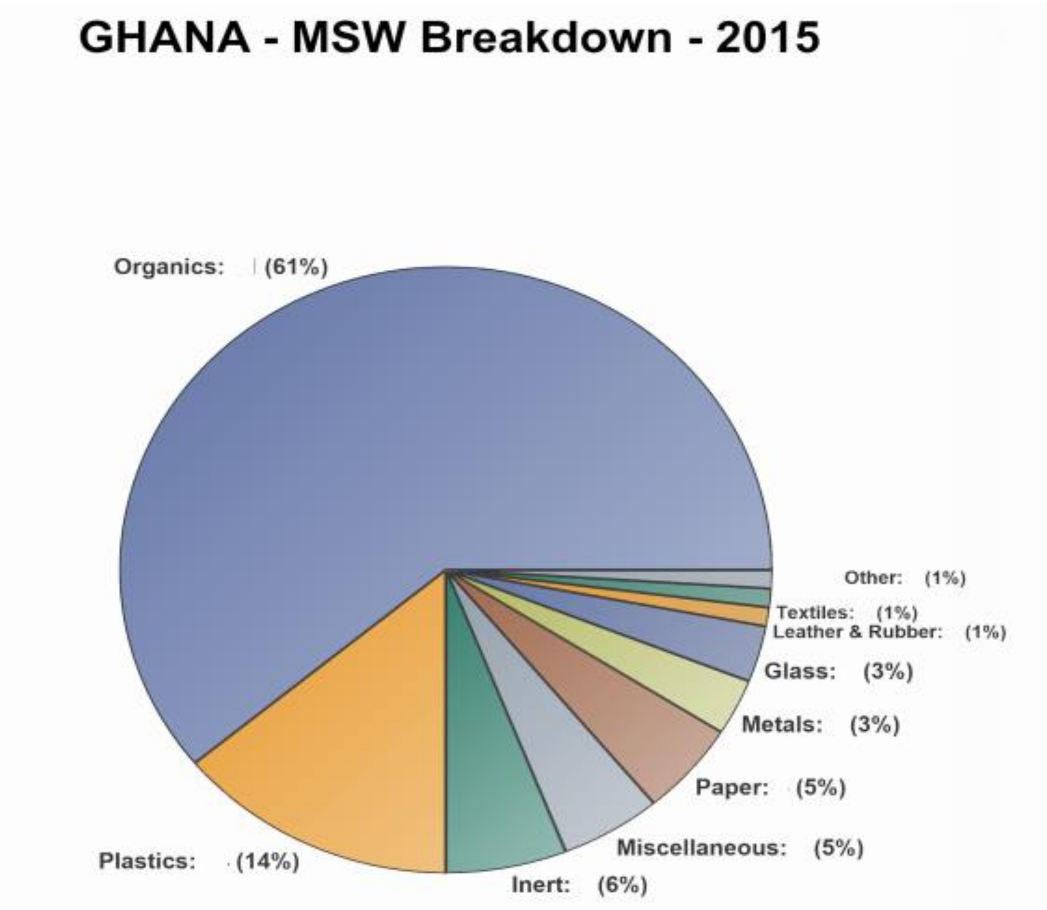
Waste should be seen as a valuable resource. Ghana is embarking upon a forward-thinking Integrated Waste Management Strategy, one which could include Zero waste to Landfill by the adoption of New Energy Management Plants that produce electricity, Renewable Energy. Findings from existing studies have been utilised within this report in order to quantify the MSW tonnage per year, understand the waste characteristics and propose Short Term, Medium and Long- Term Waste Strategies and Technologies. The new Government propose four Landfill sites at Sunyani, Wa, Bolgatanga and Konoridua and two Transfer Stations Rapid urbanisation in major cities of Ghana puts immense pressure on the existing infrastructure facilities among which, one such sector is Municipal Solid Waste Management or MSWM. Existing infrastructures are not adequate to deal with the increasing quantities of MSW. The major reason for this by the old Government was poor project planning and implementation of rules and regulations and lack of Knowledge about the various technologies available, best management practices and understanding fundamentals of MSWM. We propose an Energy Plant of 35MWh in size generating 840 MWh per day or 380,192 MWh year of electricity. Appendices reveal in detail how this can be achieved by the New Government.

For Ghana to achieve Sustainable Waste Management it is necessary to develop good waste collection, transportation, treatment, recycling and disposal methods and to understand the various treatment technologies such as PENNGATE's recommendation to use Integrated Waste Management Energy Plants that will see ZERO requirement for Landfill and Zero Emissions from the electricity produced. Ghana should developer proper MSWM systems that require involvement of all aspects of planning and designing and Integrated Solid Waste Management (ISWM) system such as technical, Political, Environmental, Financial, Socioeconomic, legal and cultural aspects. We need to focus down on waste from ACCRA first to make a good statement for good Waste Management in Ghana. Previously, the four landfill sites indicated in this Project No. 2 were a possible solution and not set as a definitive plan, then, in view of the fifteen Waste Transfer stations currently in ACCRA we should utilise that waste as a feedstock to our New Energy Plant. We also should close the Oblogo landfill sites and cap it and then site another New Bioreactor Landfill site close to ACCRA where waste from ACCRA Transfer Stations can be stored. We can of course add two of the other landfill sites from the list in the original brief if required as a choice for the Government. with Zero new waste going to Landfill with Zero emissions and Revenue generation over a twenty-five-year period. Transfer Stations will cost $350,000 each & Bioreactor Landfill $8.96 million each.

This report will cover all aspects of MSWM, the various component systems, such as collection, transportation, processing and disposal, and their integration. Various component technologies available are recommended for the treatment, processing and disposal of MSW. **As mentioned earlier, a successful MSWM system is the result of proper planning and strategy.** ***MSWM details are covered comprehensively in this report, initially the MSW tonnage produced in Ghana has been assessed as 5.054 million tonnes per year growing at 2.18% per year followed by analysis of the mechanisms for MSW generation and its composition, characteristics and scenarios in developing Countries. MSWM practices in developing Countries like Ghana are also investigated, laws, legislation and the role of Municipal corporations and ragpickers in MSWM. Collection and transportation methods for MSW and provides various biological and thermal treatment processing methods such as Medium and long term technological techniques such as composting, bio- methanation, Gasification and Incineration. Long Term reuse of waste products is investigated with a view to manufacturing new goods and revenue generation and Recycling techniques such as Material Recovery Facilities (MRF's) recommended for the Long-Term. A new approach to MSWM and other disposal methods from landfill and the environmental impacts of landfilling. Development drivers are detailed for the development of MSW from Low and medium income Countries such as Ghana and systems engineering principals discussed together with centralised and decentralised waste management systems.investigated such as sanitary landfilling, biogas recovery.***

The existing landfill sites in Accra are reaching full capacity and the acquisition of land for the construction of landfill sites has become very difficult due to rapid developmental activities in Accra. However, with the current rate of development which will cause the construction of landfill sites to be far from the source of generation, there is urgent need to get an intermediate facility, that is, waste transfer station where waste would be processed and compacted in long distance trucks to reduce the cost of waste transport and disposal. The Waste Characteristics are now needed to be understood in irder to develop proper SWM strategy.

Fig 1. What is the Municipal Solid Waste Characteristics in Ghana.



Source:

Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana

Kodwo Miezah [a], Kwasi Obiri-Danso [a], Zsófia Kádár [c,*], Bernard Fei-Baffoe [a], Moses Y. Mensah [b]

[a] *Department of Theoretical and Applied Biology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[b] *Department of Chemical Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[c] *Department of Chemical and Biochemical Engineering, Technical University of Denmark (DTU) DK 2800, Kgs, Lynbgy, Denmark*

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Oblogo - Close old Landfill site

ACCRA - New Bioreactor Landfill site

ACCRA - New Energy Plant

Table 1

Waste Types processed in Energy Plant

Paper & cardboard	1.	Newspaper
	2.	Cardboard/boxboard
	3.	Magazines/catalogues
	4.	Office paper
	5.	Other/miscellaneous paper
Glass	6.	Clear containers
	7.	Green containers
	8.	Amber containers
	9.	Remainder/composite glass
Metal	10.	Tin/steel containers
	11.	Aluminium containers
	12.	Other ferrous metal
	13.	Other non-ferrous metal
	14.	Major appliances
Plastics	15.	Clear PET bottles/containers
	16.	Green PET bottles/containers
	17.	Amber PET bottles/containers
	18.	HDPE containers
	19.	Film plastics
	20.	Other plastics
Textiles	21.	Textiles
Organics	22.	Food waste
	23.	Garden waste
	24.	Agricultural waste
	25.	Abattoir waste
	26.	Remainder/composite organics
Construction & demolition material	27.	Concrete
	28.	Lumber
	29.	Remainder/composite C&D
Hazardous wastes	30.	Paint
	31.	Hazardous materials
	32.	Biomedical
	33.	Batteries
	34.	Oil filters
	35.	Remainder/composite waste
Other waste	36.	Electrical and electronic equipment
	37.	Tyres
	38.	Furniture
	39.	Ceramics
	40.	Other

Source:

[1] UNEP/IETC (2009). *Developing Integrated Solid Waste Management Plan, Volume 1,* *Waste Characterisation and Quantification with*

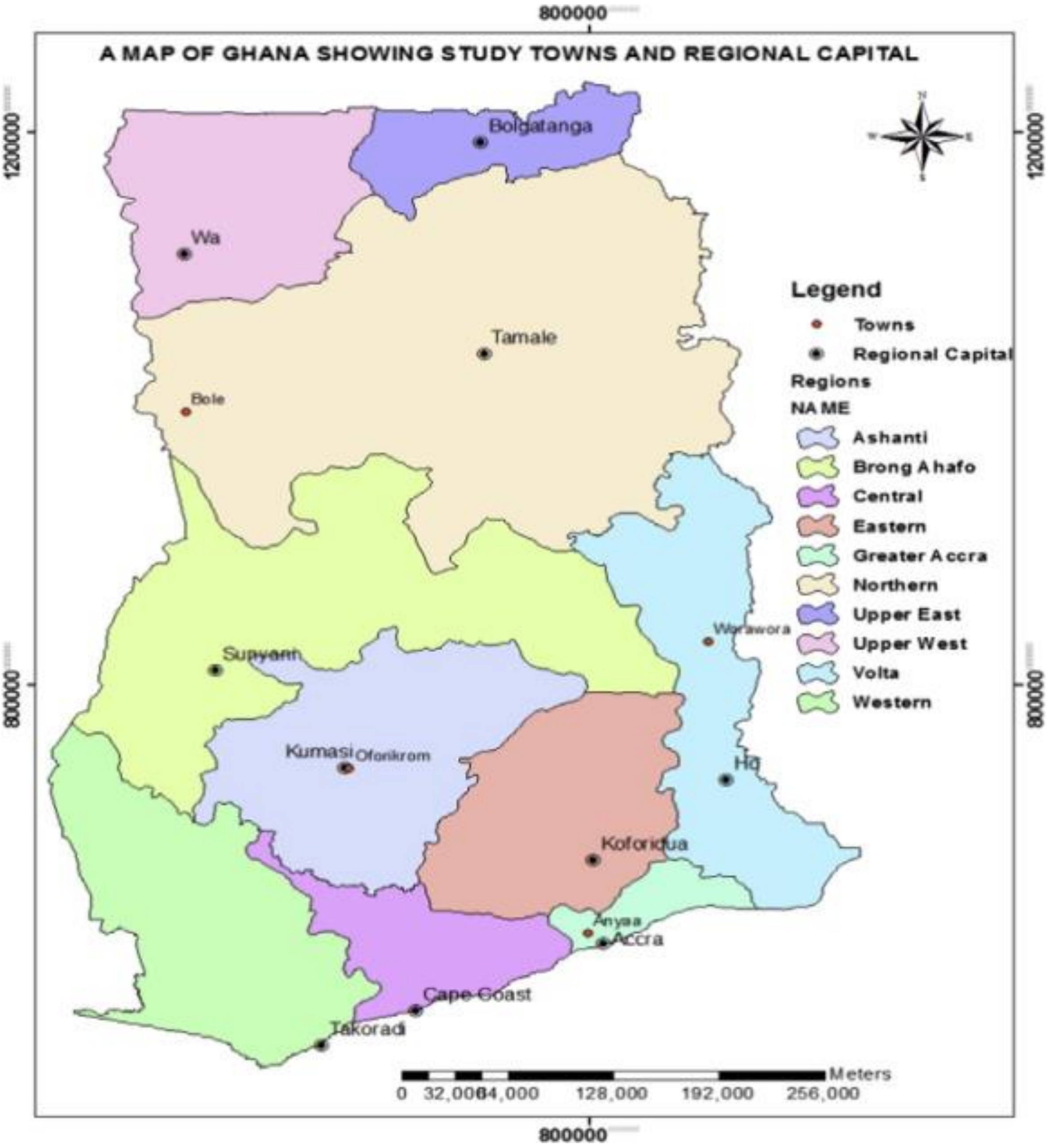
MSW Analysis – Study performed in Ghana 2015

Randomly selected households from the study location as shown in Fig 2 were visited to inform occupants about the survey and to receive feedback on their willingness to participate in the study. Using University students that had earlier been trained on how to solicit responses on the designed questionnaire, questionnaires were administered to obtain data on socio-economic, demographics, educational level, knowledge on waste management and reasons for willingness to participate. The selected households were earlier educated over a two day period on waste sorting and separation using designed flyers and personal contacts.

Initial sorting of the waste was carried out by members of the households and further sorting was done by the research team. Two bins or polythene bags were supplied to each household for the sorting and separation, to organic wastes and all other waste. The organic waste bin was labeled "Biodegradables except paper" which included food/kitchen waste, leaves, tree branches, wood waste, and agricultural waste) while the "Other wastes" comprised plastics, papers, textiles, metals, glass, rubber, leather and any waste which could not be classified.

In order to avoid significant undesired changes in the composition of the waste separated by households, especially the organic fraction, further sorting was done every two days and or at least twice a week for a period of 3–5 weeks. The Sorters, Supervisors and Recorders were trained in theory and practice on all aspects of the sorting, measurement and recordings on excel sheet. Number of Sorters per household per sorting day was of ratio 1 Sorter to 5 households, but for the sake of efficiency, the Sorters worked in a group of 6. Thus the 6 Sorters worked on 30 households per day. A total of 18 Sorters were used in all the three settlement areas per a region; complimented with 6 Supervisors who coordinated the collection as well as the transportation of the waste to the sorting venue and 3 Recorders for data entry. Personal protective equipment was provided for each person involved in the study.

Fig 2. Areas of MSW – sorting and Data Analysis in the study



Source: 2015 - Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana

Table 2

Generation of household waste from households in the Regional capitals of Ghana.

Regional capital	2014 Population estimate based on inter-census growth rate from 2010 census	High class income area/ kg/p/day	Middle class income area/kg/ p/day	Low class income area/ kg/p/day	Average generation rate kg/p/day	Total waste generation based on population/tonnes	*P*-value
Takoradi	605673	0.76	0.68	0.65	0.70	424	0.7299
Cape coast	191961	0.74	0.69	0.58	0.67	128	0.3690
Accra	2088723	0.86	0.73	0.62	0.74	1552	0.2666
Ho	300106	0.34	0.33	0.27	0.31	94	0.6412
Koforidua	199653	0.80	0.54	0.48	0.61	122	0.0004
Kumasi	2263914	0.63	0.73	0.86	0.75	1689	0.3189
Sunyani	134958	0.52	0.49	0.47	0.49	66	0.6967
Tamale	416338	0.38	0.27	0.36	0.33	137	0.2178
Bolgatanta	137979	0.31	0.20	0.20	0.21	29	0.0024
Wa	115627	0.30	0.23	0.21	0.25	29	0.0075
Average Regional Capitals	645493	0.56	0.49	0.47	0.51	427	0.3788
Non-regional capitals							
Anya	30345	0.57	0.44	0.48	0.53	16	0.0789
Bole	65695	0.42	0.26	0.22	0.3	20	0.00007
Worawora	67950	0.26	nd	nd	0.26	18	
Average Overall	509148	0.53	0.46	0.45	0.474		
Std		0.30	0.20	0.21	0.22	669	
Max.		0.86	0.73	0.86	0.746	1689	
Min.		0.26	0.20	0.20	0.209	29	

nd means not done.

Source: 2015 - Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana

Waste generated per person in Ghana

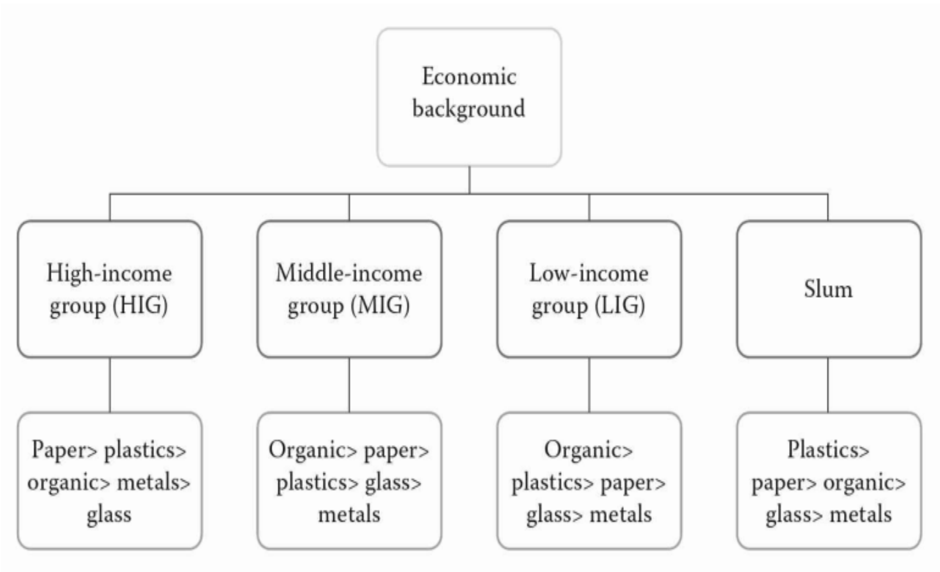
MSW is a multidisciplinary activity that is not only based on urban and regional planning, but also involves engineering principles along with economic and social issues. The management of MSW starts from the point of generation up to disposal. To carry out the vast task of MSWM, the system requires resources in the form of manpower and machinery for MSW handling operations, such as collection, transportation, loading, and unloading of waste. Vehicles and heavy earthmoving equipment are needed at landfill sites for its ultimate disposal. Another concern for the management of MSW is that it should be designed, planned, and operated in such a way that there should be minimal damage to the environment.

On the average, rate of waste generation was 0.51 kg/person/day for all the ten regional capitals and that for the other study areas aside the regional capitals was 0.47 kg/person/day Table 2 The Kumasi metropolitan area recorded the highest waste generation rate of 0.75 kg/person/day which was slightly above that of the capital city Accra, 0.74 kg/person/day. Waste generation within four of the five metropolitan areas studied; Accra, Kumasi, Takoradi, and Cape Coast had on the average 0.72 kg/person/day compared to Tamale which was lower 0.34 kg/person/day Table 2 The much lower waste generation rate in Tamale could be attributed to the low economic activities in the area compared to the other four metropolises and other municipalities in the Coastal and Forest zones. The least was recorded in Bolgatanga municipality, 0.209 kg/person/day. The average per capita household waste generation obtained for the metropolitan cities, except Tamale, was comparable to the 0.75 kg/person/day generation rate reported for all metropolitan cities in Ghana by the Ministry of Local Government and Rural Development (MLGRD, 2010) in a forecast of National Environmental Sanitation Strategy and Action Plan (NESSAP) 2010–2015. Again the 0.45 kg/person/day predicted by the same source and also by Mensah and Larbi (2005) for all other cities and towns in the districts and municipalities is below the average generation rate for regional capitals (0.51 kg/person/day), but closer to the average generation rate (0.47 kg/person/day) for the whole of Ghana as reported in this research.

Reliable national data on waste generation and composition that will inform effective planning on waste management in Ghana is absent. To help obtain this data on a regional basis, selected households in each region were recruited to obtain data on rate of waste generation, physical composition of waste, sorting and separation efficiency and per capita of waste. Results show that rate of waste generation in Ghana was 0.47 kg/person/day, which translates into about 12,710 tons of waste per day per the current population of 27,043,093. Nationally, biodegradable waste (organics and papers) was 0.318 kg/person/day and non-biodegradable or recyclables (metals, glass, textiles, leather and rubbers) was 0.096 kg/person/day. Inert and miscellaneous waste was 0.055 kg/person/day. The average household waste generation rate among the metropolitan cities, except Tamale, was high, 0.72 kg/person/day. Metropolises generated higher waste (average 0.63 kg/person/day) than the municipalities (0.40 kg/person/day) and the least in the districts (0.28 kg/person/day) which are less developed. The waste generation rate also varied across geographical locations, the coastal and forest zones generated higher waste than the northern savanna zone. Waste composition was 61% organics, 14% plastics, 6% inert, 5% miscellaneous, 5% paper, 3% metals, 3% glass, 1% leather and rubber, and 1% textiles. However, organics and plastics, the two major fractions of the household waste varied considerably across the geographical areas. In the coastal zone, the organic waste fraction was highest but decreased through the forest zone towards the northern savanna. However, through the same zones towards the north, plastic waste rather increased in percentage fraction. Households did separate their waste effectively averaging 80%. However, in terms of separating into the bin marked biodegradables, 84% effectiveness was obtained whiles 76% effectiveness for sorting into the bin labeled other waste was achieved.

Source: Elsevier – Municipal Solid Waste Characterization and qualification as a measure towards effective waste management in Ghana - Volume 46, December 2015

Fig 3 Schematic flow diagram to understand MSW generation in the different economic sectors



Source:

Municipal Solid Waste Management in Developing Countries

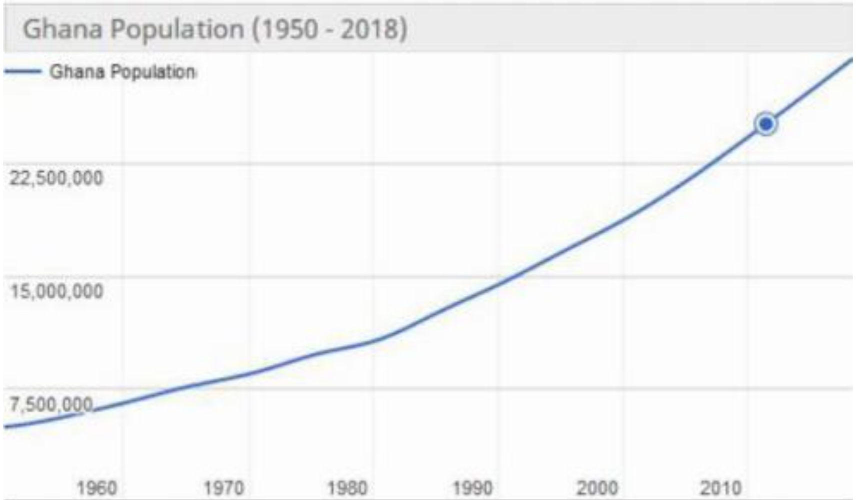
International Standard Book Number-13: 978-1-4987-3774-6 (Hardback) Sunil Kumar

Population of Ghana (2018 and historical) – MSW waste produced in Ghana 5.054 million tonnes per year.

Year	Population	Yearly % Change
2018	**29,463,643**	**2.18 %**
2017	28,833,629	2.22 %
2016	28,206,728	2.26 %
2015	27,582,821	2.39 %

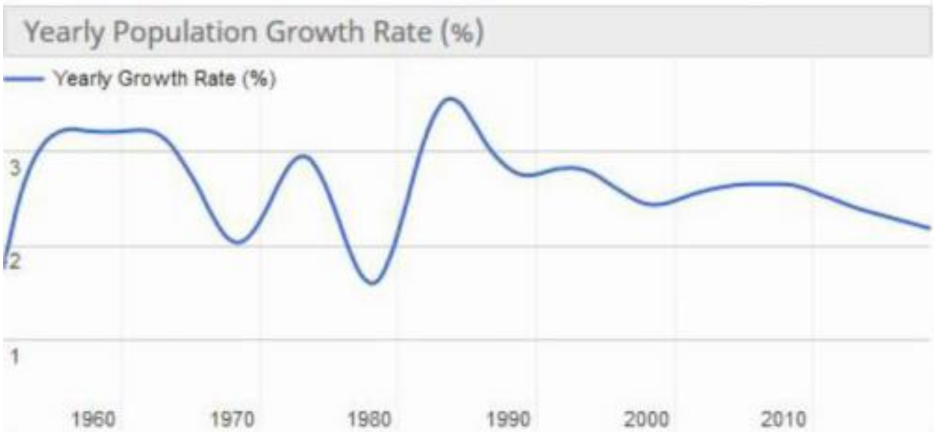
Source: http://www.worldometers.info/world-population/ghana-population/

Fig 4. Ghana Population 1950 - 2018



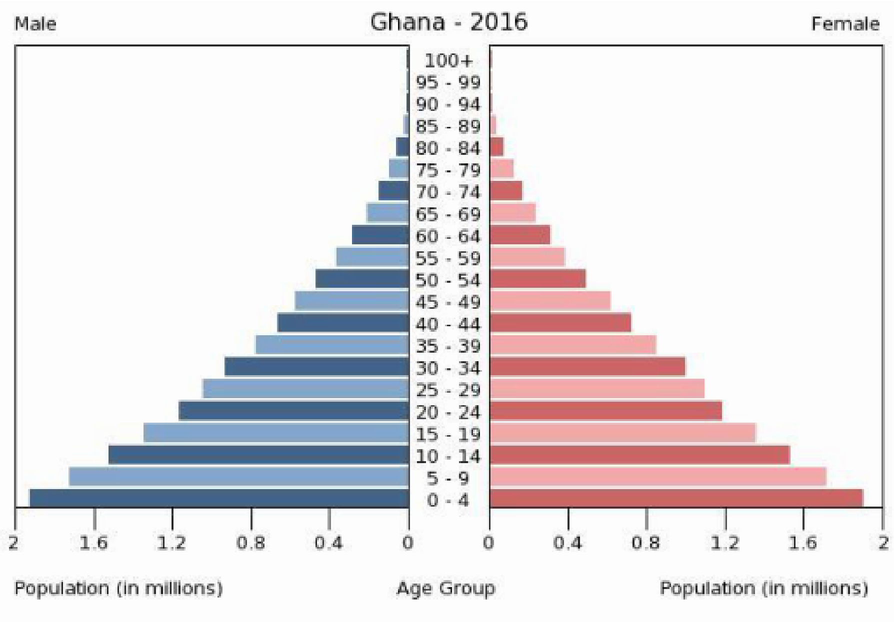
Source: http://www.worldometers.info/world-population/ghana-population/

Fig 5. Ghana - Yearly Population Growth



Source: http://www.worldometers.info/world-population/ghana-population/

Fig 6. Ghana – Male / Female demographics - 2016



http://www.worldometers.info/world-population/ghana-population/

Using the population data above and the per capita MSW produced each day is 0.47kg per person per day per person then the annual production of MSW will be –

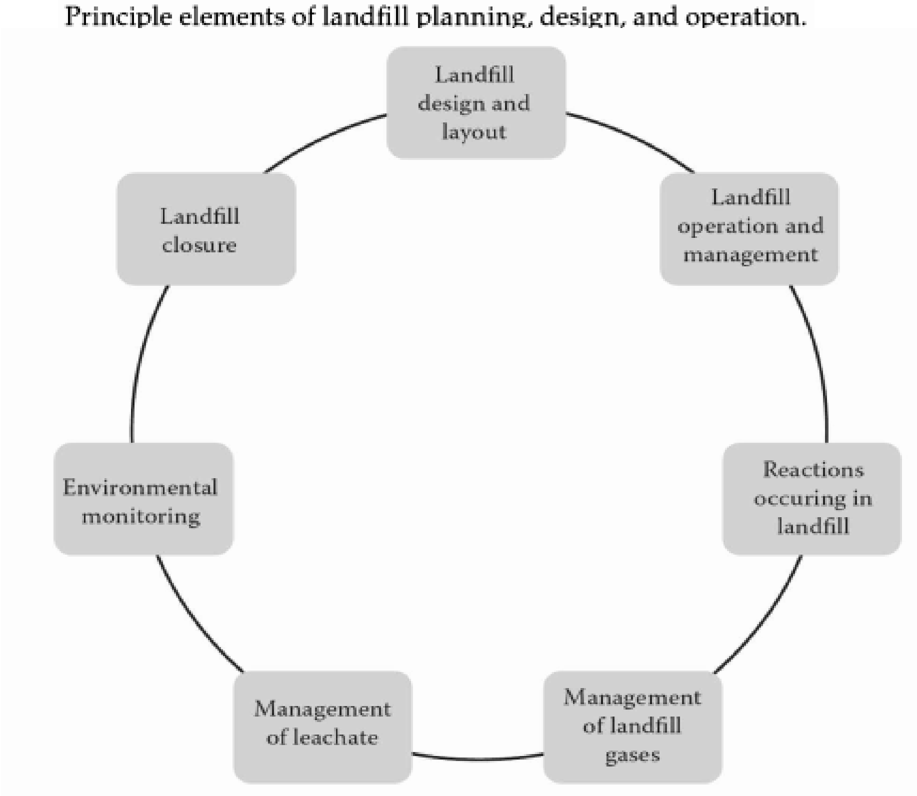
13,847.91 tonnes per day or 5.054 million tonnes per year.

Condition of central waste collection container at Amanful.

3. *Short-Term*

Fig 7. Bioreactor Landfill site, possibly at ACCRA producing eletctricty in year one & Energy Plant with Zero Emission & Zero Waste to Landfill in the future two year period.

Principle elements of landfill planning, design, and operation.



Source: Municipal Solid Waste Management in Developing Countries – 2015 - International Standard Book Number-13: 978-1-4987-3774-6

In this section we look at Landfill. Oblogo Landfill ACCRA should be closed and capped. A New Bioreator Landfill should be constructed with others developed over the next five years producing electricity. As indicated, one of the roles of the EPA is to prescribe standards and guidelines concerning the discharge of wastes and control of toxic substances. To date three relevant guideline documents have been published:

- Ghana Landfill Guidelines, May 2002;
- Guidelines for the Management of Healthcare and Veterinary Waste in Ghana, 2002; and
- Best Practice Environmental Guidelines Series No. 3 – Manual for the Preparation of District Waste Management Plans in Ghana, July 2002.

The Ghana Landfill Guidelines published by the EPA are an attempt to promote the phased upgrading of landfills, initially by improving site selection, waste compaction and drainage resulting in 'High Density Aerobic Landfills' (target is for all Metropolitan, Municipal and Large Urban landfills by 2010) and culminating in achieving operation of 'Sanitary Landfills' by 2020 (again for larger landfills). Progress is being made to achieve these targets, PENNGATE can assist.

The planning manual refers to the acceptability of disposal of industrial wastes at municipality landfills provided these are "previously identified and quantified by the assembly for handling". The guidelines do not clarify the meaning of this, but it is presumed that this means that if an enterprise has quantified its wastes which are suitable for landfill and the municipality landfill has adequate planned capacity then the wastes can be accepted for landfill.

Landfill - initial requirement before Energy Plant is operational

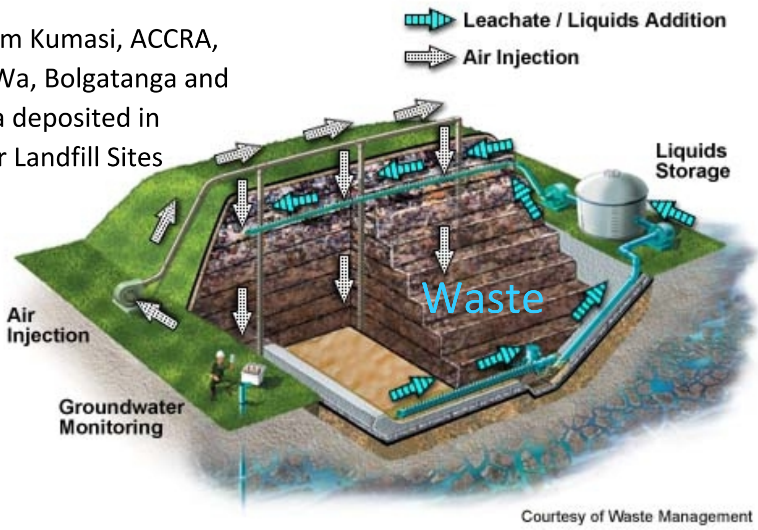
The New Government in Ghana have identified the need for four new Landfill sites at Sunyani, Wa, Bolgatanga and Konoridua and two Transfer Stations at each landfill site. PENNGATE propose that the Landfill sites should be Bioreactors in year one then after two years and all wastes will be diverted into the Medium / Long Term Energy Plants and Integrated Waste Management Plants. **A New Bioreactor Landfill site for ACCRA producing electricity.**

The new Bioreactor Landfill is an initial requirement until the Energy Plant is operational.
The Sekondi-Takoradi Metropolitan Assembly (STMA) is negotiating to reactivate a project with World Bank funding and a company is currently re-finalising the design of the landfill site at Sekondi-Takoradi. PENNGATE would advise contunue this project and to make this a temporary solution over the next two years and then an Energy plant could be sited at this site in the future to take the existing waste as a feed-stock to the Energy Plant.
Unfortunately, STMA is currently depositing waste at the site of the stalled World Bank landfill. At present the waste is being deposited away from the partially engineered leachate treatment area of the site but within the Phase 3 fill area. There is a risk that the longer this uncontrolled operation continues the more of the site will be unavailable for Phase 3 or even Phase 2 development. This waste could of course be moved to Phase 1 when it opens but this will make operations more complex and result in Phase 1 filling very rapidly. If the uncontrolled tipping at the site continues for much longer the World Bank may consider that the original plans to develop the site as a modern engineered landfill are no longer viable. It must be assumed that, in the short term, the only 'landfill' which will be available for solid wastes in the Takoradi area will be this site. It is currently operating as an uncontrolled dump; over which the EPA has expressed deep concern. Turn these into a Bioreator Landfill sites.

Current good landfill design is to divide a site into smaller cells where waste is deposited to limit the amount of leachate (liquid) being generated. Given that Sustainable Sanitised Landfill sites will require more finance, large volumes of water for flushing with associated infrastructure for treating the disposing of the leachate, there will be NOT the same emphasis on leachate minimisation as the four Landfill sites should be seen as possible Bioreactors. Normally, except in large landfill sites it is required to split the landfill sites into smaller cells, so the working face of the landfill may progress over the whole floor of the landfill on one lift before commencing the next deposition layer of waste. There will be need for the construction of inter-cellular bonds in our Bioreactor Landfill sites.

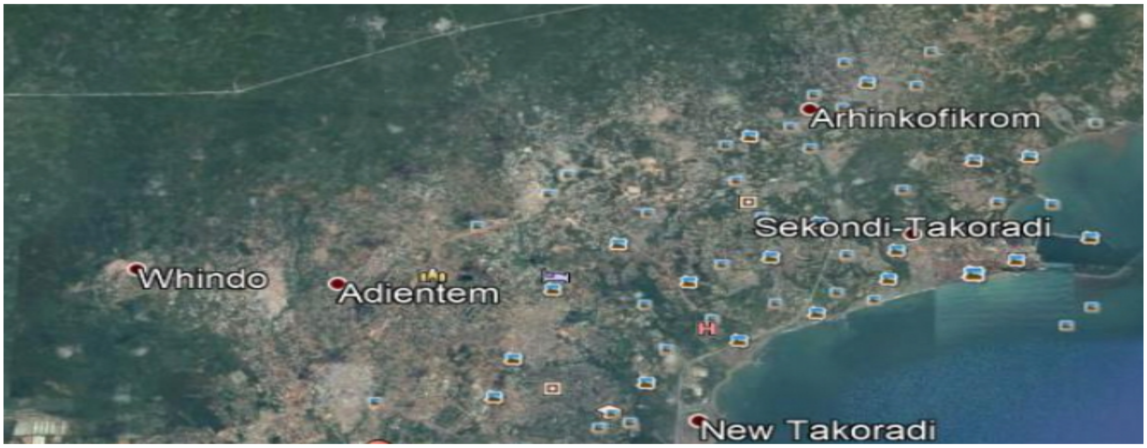
For example - 2.4 MW will produce 21024MWh per year @ $185 per MWh = $3,889,440 per year in selling electricity to ECG.

Waste from Kumasi, ACCRA, Sunyani, Wa, Bolgatanga and Konoridua deposited in Bioreactor Landfill Sites



A New Bioreactor Landfill site for ACCRA producing electricity and New Energy Plant, funding provision of $315 million via PSECC Ltd & PENNGATE made for the site in the project finacials for the Waste Project No. 2

Sekondi-Takoradi Landfill location in Western Region



Oblogo Landfill location in Central Region near ACCRA

With reference to the origional brief of four engineered Landfill sites constructed in Sunyani, Wa, Bolgatanga and Koforidua and eight transfer stations with three mini transfer stations at Ashiaman, Tema and pokuase.

PENNGATE are initially proposing that in the short term the Landfill sites should be constructed on a Bioreactor Landfill basis producing electricity and then over time lager Energy Plants with Zero Emission and Zero waste to Landfill to promote cleanliness and public health.constructed. The construction of the new Bioreactor Landfill sites and Transfer stations in the regional capitals will improve solid waste management (SWM).

PENNGATE propose that the first Bioreactor Landfill should be at either Kumasi or ACCRA the Countries Capital City and also construct a New Energy Plant which in time will mean No Landfill" requirement. Following this first site at ACCRA then the Energy Plant can be constructed at Sunyani, Wa, Bolgatanga and Koforidua. These new measures must not just be short term but Sustainable for future generations.

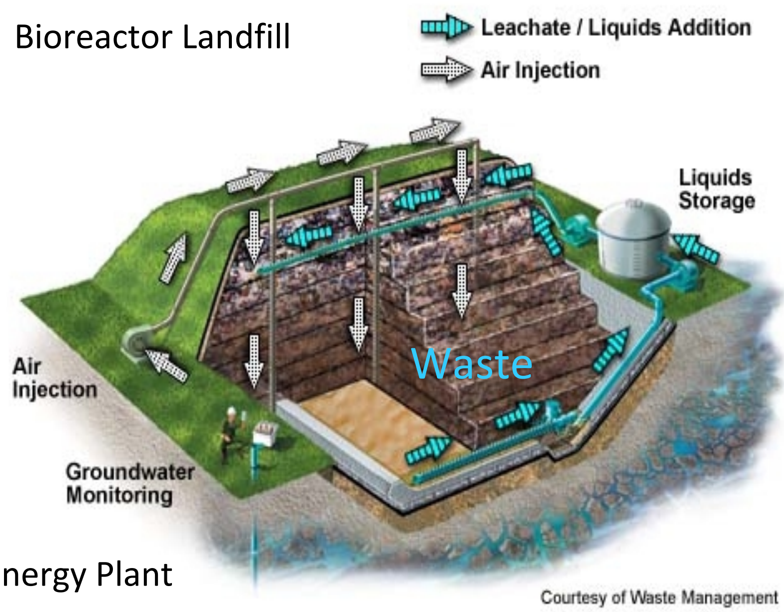
Kumasi - 1,000 acres of land has been procured for Renewable Energy projects and Kumasi would be a good site for a new Bioreactor Landfill and new Energy Plant.

Ashanti Region

Population Size and Growth Rates
The Kumasi metropolis is the most populous district in the Ashanti Region. During the 2000 Population Census it recorded a figure of 1,170,270. It has been projected to have a population of 1,625,180 in 2006 based on a growth rate of 5.4% p.a and this accounts for just under a third (32.4%) of the region's population. Kumasi has attracted such a large population partly because it is the regional capital, and also the most commercialised centre in the region

Kumasi will soon have a solar farm

Bioreactor Landfill



New Energy Plant

Possible New Bioreactor Landfill site at ACCRA

Old Oblogo Landfill site - ACCRA

Impact of Improper Municipal Solid Waste Landfilling

Short-Term Impacts	Long-Term Impacts
Noise, flies, odor, air pollution, unsightliness, and windblown litter. Such nuisances are generally associated with waste disposal.	Pollution of the water regime and landfill gas generation.

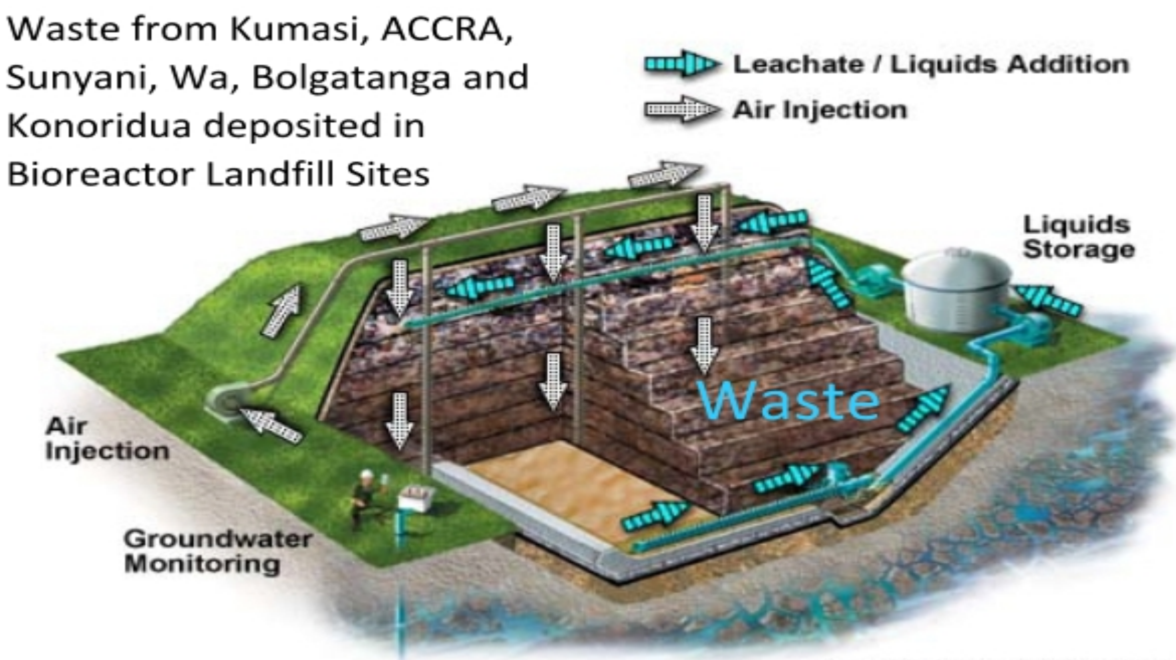
PENNGATE recommend a Bioreactor Landfill site for ACCR, the other Landfill sites proposed oould be viewed and engineered to produce electricity from ACCRA's MSW until the Energy Plants are built and operational in the Medium-Term and also Long-Term strategy. By making these landfill sites temporary it means the costs are significantly reduced when compared to a full sanitized Landfill site with Leachate and gas collection. The Chartered Institute of Wastes Management in the UK has produced guidance on Landfill sites -extracts of the following report have been used in this report "The role and Operation of The Flushing Bioreactor" Over time there will be reduced need or indeed no need for Landfill sites in Ghana.

Several points in the preceding sections have implications for the location of a flushing bioreactor site. Current policy tends to favour landfills located where they achieve reclamation of land such as redundant quarry workings, which may be some distance from population centres. They may be located close to sensitive waters such as groundwaters abstracted for drinking water or high quality rivers and streams.

During its relatively short life, a flushing bioreactor may pose a greater threat to groundwater than a conventional site. It is important that the engineering is sufficient to ensure containment. In the longer term these risks will be eliminated as the pollution potential of the waste is removed.

Sekondi-Takoradi Landfil

Bioreactor Landfill & waste transfer stations



Bioreactor Landfill sites & Transfer stations - Our UK partner comany CQA

CQA International has expertise in the planning of municipal, industrial and hazardous waste management systems and has developed Integrated Waste Management plans for both government and industrial clients in several states of the former USSR and the Middle East. We have also undertaken projects concerning waste recycling, composting and incineration.

Our Waste Management service incorporates the planning, design and implementation of new waste management sites and the remediation of existing waste disposal sites. All feasibility studies; permitting; EIA; construction supervision; contractual management; compliance verification and monitoring is undertaken by CQA.

Bioreactor Landfill & waste transfer stations

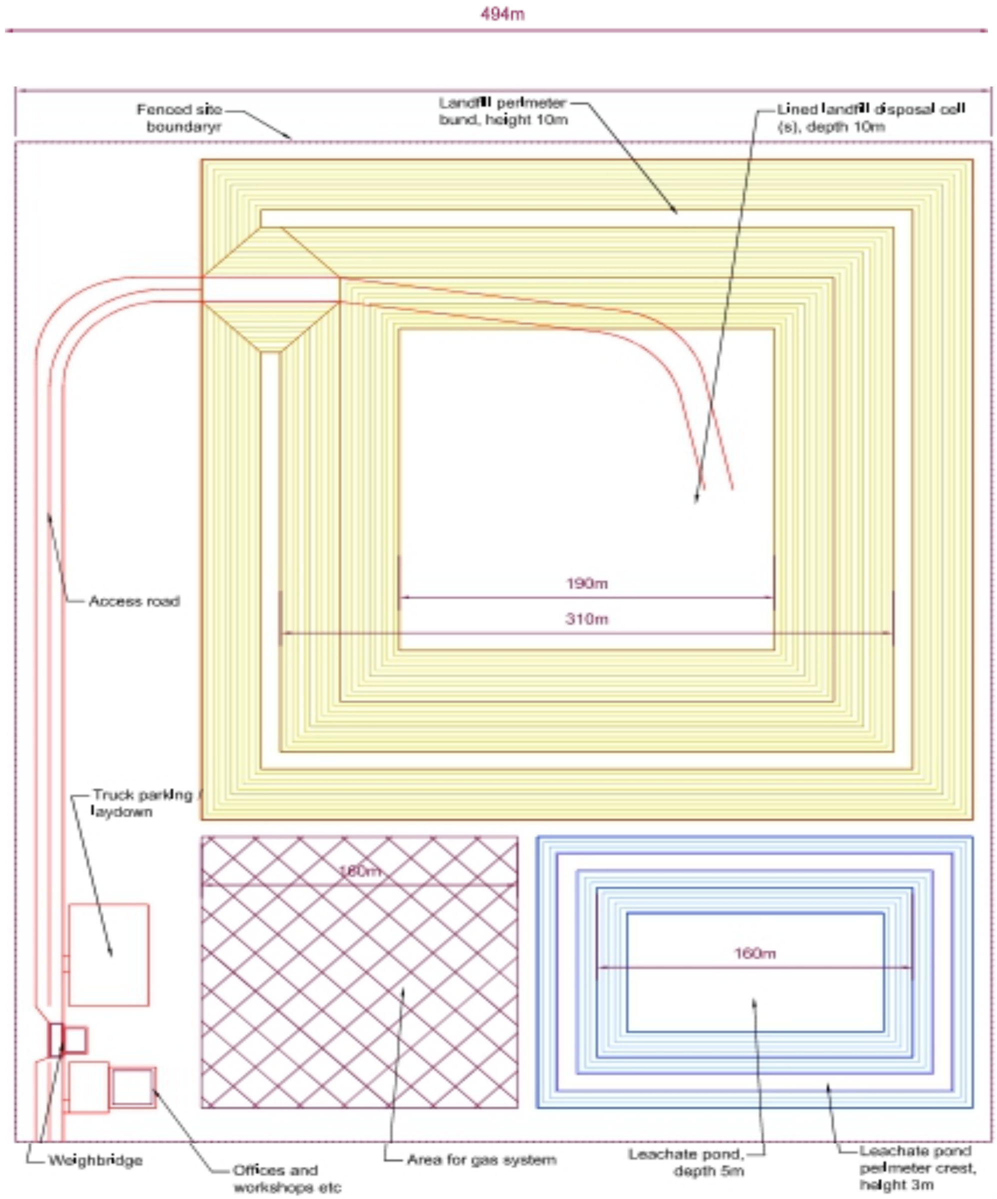
Linned, engineered, electricity producing Landfill sites.

CQA International is experienced in the design, construction and Quality Assurance of EU compliant landfills for both hazardous and non-hazardous wastes and has been responsible for all stages of the development of landfills in the UK, Ireland, Portugal, Azerbaijan, Turkey, Georgia, Romania, Cyprus & Kuwait.

Landfill projects entail the detailed design of landfill facilities, waste to energy incinerators and closure to EU standards; contract and construction management; permitting; CQA and compliance reporting and environmental protection. CQA was established in 1993 and now operates throughout the world, with offces in the UK and Azerbaijan. Our team of 30 have been carefully selected to give us a breadth of experience across multiple engineering disciplines, providing us with both the technical expertise and practical ability necessary to focus on clients'requirements and to consistently understand and solve their problems.

We have a wealth of varied and diverse experience that includes the design and construction of mining infrastructure, EU compliant landflls, waste management and recycling, composting and incineration, and have worked with major waste management corporations, oil companies, government organisations, mining companies plus projects funded by the EU and World Bank. Weŕe proud of the highly personal service we provide, and we know how highly thatš valued by our clients. Our senior team works on each and every project, spending time getting the detail right, perfecting everything to make sure the end result meets the brief exactly.

An EU funded project included the construction supervision of 3 large regional landfll complexes with medical waste autoclave facilities, 2 leachate treatment plants, 10 waste transfer stations and the rehabilitation of 15 old dump sites. CQA provided technical and contract management of the construction contracts in addition to redesigning most facilities to suit actual conditions. CQA also provided input to the institutional strengthening tasks, such as waste collection routing, recycling initiatives and training.



CONCEPTUAL SKETCH OF SANITARY LANDFILL FOR GAS GENERATION
Scale 1:2500 at A4 size

Bioreactor Landfill site with electricity production

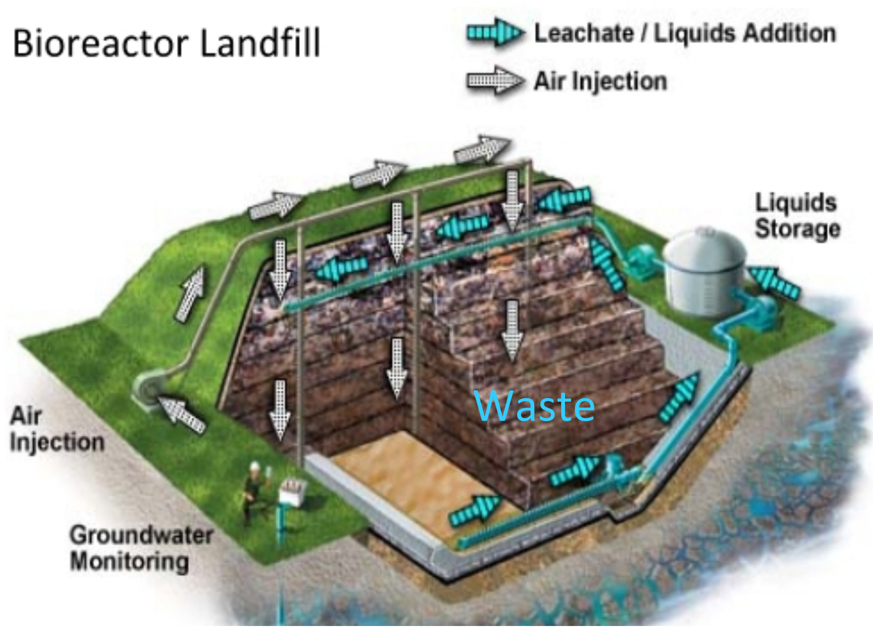
We have developed a concept design for a Bioreactor landfill with nominal capacity 1 million tonnes of waste for Kumasi & ACCRA.

It is designed to accommodate filling in such a way as to promote gas generation from early in the cycle. This is just an outline sketch for now, without operational details.

A construction cost estimate is as follows. We have based this on rates from several countries in the middle east and central Asia. We dont know how similar costs will be in Ghana and further investigation is required. No contingency is included. We have allowed for a fully functional Bioreactor site.

We have also provided some indicative costs for simple transfer stations. We will make some estimates of gas generation at a later stage, which may be able to provide income and, at least, offset landfill costs.

Bioreactor Landfill costs for a 1 million tonnes per annum (tpa) site - $8.96 million - site will pay for itself due to electricity production.



Landfill estimated construction costs

	Unit	Quantity	Rate, $	Amount, $
Contract misc costs	sum	1	50000	50,000.00
Preparatory Works	sum	1	30000	30,000.00
Excavations and Embankments	m3	500000	4	2,000,000.00
Lining system	m2	80000	25	2,000,000.00
Leachate Drainage System	sum	60000	12	720,000.00
Leachate Pond	sum	1	400000	400,000.00
Weighbridge	sum	1	100000	100,000.00
Internal Roads and Pavements	m2	12000	25	300,000.00
Storm Water Drainage	sum	1500	15	22,500.00
Buildings	sum	1	30000	30,000.00
Fence and gates	m	2250	30	67,500.00
Water Supply and Sanitation	sum	1	20000	20,000.00
Power Supply and Distribution	sum	1	100000	100,000.00
Leachate Treatment Plant	sum	1	500000	500,000.00
Gas Collection and Flare	sum	1	600000	600,000.00
Gas generator	MW	2	250000	500,000.00
Landscaping	sum	1	20000	20,000.00
Allow for capping and closure	sum	1	1500000	1,500,000.00
Total				8,960,000.00

Bioreactor Landfill with electricity production

Many waste materials (paper, wood, food, plant trimmings) contain significant quantities of carbon. The carbon is primarily bonded in a variety of “organic” molecules, i.e. hydrocarbons with traces of other elements (oxygen, nitrogen, chlorine and metals). These break down at different rates and under different conditions. Some carbon compounds, such as found in many food wastes, break down more quickly. Others, such as occur in wood and paper, are more resistant to decomposition.

Waste gasification projects aim to generate combustible gas by decomposition of the organic molecules under controlled conditions. The highest performing systems produce relatively clean hydrogen, which can be used as fuel in combustion or fuel cells to produce energy. Such systems are mostly pilot projects but the technology is expected to become widespread in the near future. Other systems produce methane, either directly and/or by reacting the hydrogen produced. This gas is also a combustion fuel that can be used in turbines or, less efficiently, in steam cycle generators.

The waste products will decompose naturally with time, in a less efficient and controlled manner. In waste bins and dump sites, the availability of oxygen will lead to the production of carbon dioxide and water. This may also occur when the waste burns. It is possible to design landfills that will minimise the oxidation of the organic molecules and lead to the production of recoverable energy, in the form of combustible gas.

Whereas gasification plants aim to achieve a high rate of conversion of the organic molecules to combustible gas, landfills generally have lower conversion rates. A common assumption is that 50% of the carbon in the waste will be converted to biogas. This may be either CH4 or CO2, depending on how the landfill is engineered and managed. Some hydrogen is also produced, but this is usually a small proportion.

The rate of conversion of the different materials varies, with food wastes degrading quickly, while wood and paper degrade more slowly. These different types of waste produce similar quantities of biogas and so the effect of the different decomposition rates is to produce gas over a relatively long period.

A landfill for waste disposal can be specially designed to optimise the generation of biogas, and also to maximise the proportion of combustible methane. Many of the design requirements are also beneficial for environmental protection and operational efficiency.

The objective is to control conditions of moisture, temperature and oxygen content. A second objective is to ensure that the waste mass is large enough to produce useable quantities of gas in the same area.

The main items to be included in the design of a “bioreactor” landfill are:

Good sealing of the base (prevents gas escape, controls water flow and helps to maintain temperature)
Phased filling in relatively small, deep cells, compared to typically wide shallow deposits in dump sites (controls oxygen input, increases compaction and temperature)

Compact the waste (controls oxygen input, prevents gas escape, increases temperature and reactions)
Install temporary cover layers (controls oxygen input, prevents gas escape, controls water flow, increases temperature, increases decomposition rate)

Recirculate leachate, if required (increases decomposition rate)

Install gas collection wells (allows sampling and testing to aid predictions, determines when utilisation can commence, used for operations extraction)

Other factors which are important to maximise energy recovery from a landfill are:

Pre-sorting of the waste to remove non-biodegradable materials
Mixing of waste types to ensure a homogenous structure and permeability
Rapid collection, transfer and deposition
Prevention of burning or other decomposition during storage

With appropriate design of the landfill and collection system, a bioreactor landfill could be producing sufficient biogas to run a small generator within one year of commencing operations. Viable gas generation should continue for at least 20 years.

A waste characterisation will allow gas quantities to be calculated. However, our recent study of a similar site suggest that 1-2 MW would be a reasonable estimate for the main period, with a peak of 3-5MW for a shorter period at and after the closure.

Each Bioreactor Landfill will produce electricity in the range of estimates, based on different models. Best to use the lower bound for any financial planning.

Assumed a relatively high content of organic (60%) carbon in the wastes and relatively dry conditions, 5 years filling, 220,000 t/y i.e. 600 td of waste which would go into the Energy plant when built, followed by closure, CV of 4.5 kWhr Nm2 (methane), installation of temporary covers and seals on exposed faces during filling. Control of transfer stations is very important in order to understand weight and Characteristics of the waste and maintain uniformed calorific value as a future feedstock for the Energy Plants.

Year	Phase	Range of continuous power output, MW	
1	filling	Low	High
2	filling	0.6	0.8
3	filling	1.2	1.6
4	filling	1.7	2.4
5	filling	2.2	3.1
6	Closed	2.6	3.8
7	Closed	2.4	3.6
8	Closed	2.2	3.5
9	Closed	2.0	3.3
10	Closed	1.8	3.1
11	Closed	1.6	3
12	Closed	1.5	2.8
13	Closed	1.4	2.7
14	Closed	1.2	2.6
15	Closed	1.1	2.4

The landfill will probably be self- financing by the time you are ready to open the WTE plant.

For example - 2.4 MW will produce 21024MWh per year @ $185 per MWh = $3,889,440 per year in selling electricity to ECG.

MSW Material Balance Converted into Energy values					
Waste Types	**kcal/kg**	**MJ/kg**	**kWh/kg**	**Volume %**	**Total kcal/kg**
Apples	590	2.47	0.69	0	0
Bamboo	3800	15.90	4.42	0	0
Bio Mass/Garden Waste	2300	9.62	2.67	11.24	259
Brown Coal	4500	18.83	5.23	0	0
Cocao Shrub	3300	13.81	3.84	0	0
Cardboard	3800	15.90	4.42	4.49	171
Cardboard Corrugated	3910	16.36	4.55	0	0
Citrus Peel	4500	18.83	5.23	0	0
China Grass	4030	16.86	4.69	0	0
Vehicle Tires	8300	34.73	9.65	0	0
Cocconut Shell	3800	15.90	4.42	0	0
Coffee Bean Shells	6000	25.10	6.98	0	0
Compost	4200	17.57	4.88	0	0
Cork	6300	26.36	7.33	0	0
Corn	4400	18.41	5.12	0	0
Cotton Seed	3300	13.81	3.84	0	0
Electronic waste					
Food Waste (Proffesional)	3700	15.48	4.30	0	0
Food Waste (Domestic)	3150	13.18	3.66	44.94	1416
Hay	3200	13.39	3.72	0	0
Household Waste Pre-Sorted	4500	18.83	5.23	0	0
Hospital Waste	6780	28.37	7.88	0	0
Leather	4020	16.82	4.67	2	80
Manure (dried)	3760	15.73	4.37	0	0
Neoprene	7100	29.71	8.26	0	0
Newspaper	3910	16.40	4.50	0	0
Nylon	7570	31.67	8.80	0	0
Oil Sludge	8800	36.82	10.23	0	0
Paper	4400	18.41	5.12	4.99	220
Paper Sludge	3910	16.36	4.55	0	0
Paper Coated	6390	26.74	7.43	0	0
Paper Adhesive	4200	17.57	4.88	0	0
Paraffin	10340	43.26	12.02	0	0
Petroleum Coke	7050	29.50	8.20	0	0
Plasic Film/Bags	8000	33.47	9.30	6.74	539
Polyethan Foam	9770	40.88	11.36	0	0
Polyethylene	10990	45.98	12.78	0	0
Polypropylene	11030	46.15	12.83	0	0
Polystrene EPS	9800	41.00	11.40	11.24	1102
Polystyrol Carbon Reinforced	10840	45.36	12.60	0	0
Rice Pods	2900	12.13	3.37	0	0
Rubber	5600	23.43	6.51	4.74	265
Sewage Sludge (Dried)	3300	13.81	3.84	0	0
Sunflower Residue	4200	17.57	4.88	0	0
Sugar Cane	3600	15.06	4.19	0	0
Straw	4000	16.74	4.65	0	0
Tobacco Powder	3000	12.55	3.49	0	0
Tar Paper	6390	26.70	7.40	0	0
Tar & Refinery Residues	9200	38.49	10.70	0	0
Tar Acid	5600	23.43	6.51	0	0
Textiles	4000	16.74	4.65	5.62	225
Wheat Flour	3640	15.23	4.23	0	0
Wood Treated	4500	18.83	5.23	1.49	67
Wood Untreated	4200	17.57	4.88	2	84
Wood - Plywood	4500	18.83	5.23	1	45
					Average kcal/kg
				100	**4472**

Transfer Stations

Transfer station with grade separated tipping area sum $250,000.00

Transfer station with compaction units sum $350,000.00

Large Transfer Stations

Smaller collection points for public to bring waste to then ZoomLion pick up skips and transport to Bireactor Landfill

Sekondi-Takoradi Landfill - World Bank funded & waste study performed

(Study details - https://www.hindawi.com/journals/jwm/2014/823752/

The rapid increase in urban population due to the influx of the citizenry in search for better conditions of life has resulted in poor environmental conditions in most urban and peri-urban settlements in the country. Municipal solid waste management (MSW) for that matter has become problematic within Sekondi-Takoradi Metropolis as the city is being inundated with so much filth which has proven to be very difficult and seemingly impossible for the municipal authorities to tackle. This study investigates the nature of solid waste problem in Sekondi-Takoradi Metropolis. A mixed methodological approach including field investigation, questionnaire survey, and structured and face-to-face interviews were employed in the gathering of data for the study. The key findings established to be the factors affecting effective solid waste management in the metropolis are irregular solid waste collection, inadequate operational funding, inappropriate technologies, inadequate staffing, inadequate skip, and lack of cooperation on the part of the citizenry.

1. Introduction

Though the need for solid waste management became necessary ever since nomadic life was discarded, the initial concern of society was on movement of waste out of the immediate human settlement. This was largely possible because, during the prehistoric era, human population was quite low and the amounts of waste generated were quite minimal and biodegradable. The proper management of solid waste became a major problem overwhelming practically all communities of the world today as a result of growing human population, changes in habits and lifestyle, rising disposable income, technological and scientific advancement, and increasingly greater production and consumption of new products. These factors have acted in concert to increase both the quantity and complexity of waste being generated. This have long rendered ineffective and detrimental any waste management strategies dependent on natures̓ capacity in the nullification of those substances. In Ghana, deficiencies in solid waste management (SWM) are most visible in and around urban and peri-urban areas. Despite the present concerns of individuals and the government about waste management in Ghana, Sekondi-Takoradi, one of the urban towns in the country, is still faced with serious solid waste management problems. The worsening solid waste situation in many urban settlements in Ghana and in Sekondi-Takoradi in particular has been a major concern both to the government and the indigenes as a whole. This is because the health implications of poor waste management can be very damaging to the people exposed to such unsanitary conditions. The rationale therefore of any proper instituted waste management is to protect the environment from the polluting effects of waste materials in order to protect public health and the natural environment. The rapid increase in population and business activities in Sekondi-Takoradi has presented several challenges which have been accompanied by a rapid increase in the volume of solid waste generated from production and consumption activities. Against this backdrop of mounting waste production, municipal authorities in Sekondi-Takoradi seem unable to organize adequate collection and safe disposal of waste within their jurisdiction.