The Potential for Climate Change Mitigation in Solid Waste Disposal: A Case Study of Lagos Landfills

Aboyade, A.O[1], Rabiu, A.*[2], Amigun, B.[3]

[1]Department of Process Engineering, Stellenbosch University, Stellenbosch, South Africa
[2]Department of Chemical Engineering, Cape Peninsula University of Technology, Cape Town 8001, South Africa
[3]National Biotechnology Development Agency, Abuja, Nigeria

rabiua@cput.ac.za

Abstract: Solid waste disposal sites account for up to 20% of global emissions of methane the second most significant greenhouse gas. However, under proper management landfills can in fact have a positive carbon balance, by capturing the methane-rich landfill gas (LFG) produced from the dumpsites. This paper assesses the potential for implementing such a project in the Olusosun waste disposal site in Lagos, Nigeria. Data regarding municipal solid wastes (MSW) generation and composition, regulations as well as relevant aspects of the Nigerian energy market and its regulations and climate change policies were evaluated. This is employed to assess the potential for a viable implementation of a landfill gas to energy project at the site. The analyses revealed that the flaring only scenario was observed to be the most economically feasible. The cost of producing electricity from LFG (approx. US$50/MWh) is higher than the estimated long term cost from natural-gas fed thermal plants (at US$39/MWh).

Key words: Lagos landfill, Climate change, Solid waste disposal

Introduction

Mounting scientific evidence linking climate change to anthropogenic greenhouse gas (GHG) emissions has given more urgency to the calls for adopting less carbon intensive economic growth (Watson, 2001). Increasing attention is being directed at developing countries where much of such future growth is expected. While it is recognized that economic growth is necessary for poverty reduction and sustainable development in these regions, global opinion leader and policy makers from both developing and developed countries agree that it would be undesirable for such growth to be sustained at current levels of carbon intensity.

There is therefore, general consensus on the need to integrate climate concerns into sustainable development objectives in all sectors of the economy; energy, transport, agriculture and waste management. Municipal solid wastes (MSW) contribute significantly to global GHG emission and are a major challenge to public health especially in lower income countries. Where proper management of solid waste disposal sites (SWDS) can be taken for granted in many developed countries, it still is a major problem for their less developed counterparts as many of these countries lack the funding and in most cases the technology to improve their disposal systems.

Emission trading schemes like the Kyoto protocol’s Clean Development Mechanism (CDM) serves as a platform for overcoming such financial and technological barriers. Under the mechanism, investors or governments in developed countries can invest in projects in poorer countries, transferring environmentally sustainable technology to help these countries reduce their GHG emissions and contributing to their sustainable development. In the process these investors are allowed to offset the certified emission reductions (CER) generated from such projects against their own emission reduction targets as set by their various countries. Many developing countries are taking advantage of this opportunity already. By 2004, India, Brazil and China, already had 42 such projects between them at different stages of implementation (Ellis, Corfee-Morlot and Winkler, 2004). This paper investigates the potential of implementing a viable landfill gas to energy project (LFGTE) in Lagos, Nigeria under the CDM mechanism. To do this, the technical potential of the project (climate, waste generation quantities, etc) as well as the relevant regulatory and socio-economic environment will be analyzed.

Methodology

1.1 Conceptual Approach

This study straddles three policy sectors, MSW, energy and climate and has clear and established benefits to sustainable development objectives in these sectors. Assessing the potential performance of an intervention such as proposed in this study requires the identification of the components and relations that could be potentially affected by that intervention (Villavicencio, 2003). In this case, introducing a technology like LFG capture will be influenced by the existing regulations and practices in the MSW, energy and climate sectors as well as physical and socio economic characteristics of the immediate environment and their dynamic interactions (Figure 1).

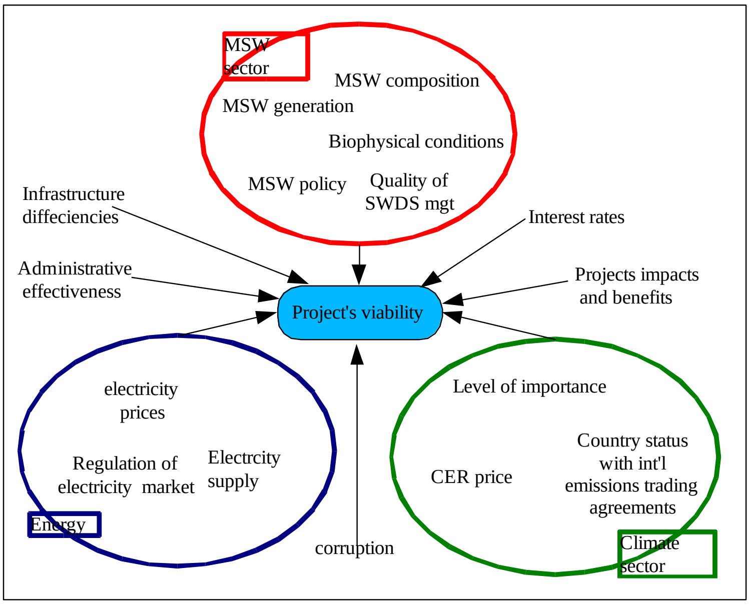

Figure 1: Conceptual map of system structure to be studied

The systems dynamics approach was used for much of the analysis done in this study. It is a method that aims to enhance the understanding of complex dynamic systems (Sterman, 2000) - dynamic, in the sense that the system variables evolve over time as the result of previous interactions (Ruth & Hannon, 1997). These variables and their interactions make up the structure of the system and determine the systems behavior. If those variables and relations can be identified, the system's behavior can then be simulated with reasonable levels of confidence (Bossel, 1994). Various permutations and combinations of the variables can also be simulated and the likely outcomes evaluated. System dynamics is here applied in analyzing the sectors shown in the conceptual map. Components within each sector interact dynamically with each other and with components in other sectors and influence the key outcome of interest i.e. the projects potential viability.

2.2 LFG Estimation Models

Many methods and models have been developed for projecting LFG generation potential from SWDS. The IPCC recommends two of these methods for LFG generation estimation for the purpose of establishing national GHG inventories – default and first order decay methodologies (World Bank, 2004). The first order decay method is the more accurate of the two and was employed in this work.

Status of MSW Management and Climate Change Policy in Nigeria

1.2 MSW Management in Lagos, Nigeria

According to Bamgbose , Arowolo, Oresanya and Yusuf (2000), 70% of total waste generated in Lagos was from domestic sources and the rest from industry (Table 1). There are widely divergent views on waste generation in Lagos. A World Bank sponsored study reported a daily generation of about 0.21 kg per capita (Bamgbose *et al.*, 2000). This figure is very likely an underestimation because it was based on records of waste received at the various disposal sites across the city. In reality about 30% of waste generated never gets to disposal sites (Agunwamba, 1998). Another study reports daily per capita waste generation rates as 0.35kg (Cygnet Services Limited, 2002).

Table 1: Waste composition in Lagos obtained from different studies

Waste Composition (%)	**(Bamgbose et al., 2000)**	**Rushbrook, Pugh, & Mundial (1999)**	**Cygnet Services Limited, (2002)**
Paper	10		10
Textiles	4	14	2
Plastic	7		22
Non food putrescibles e.g. garden waste			
Wood or straw		60	45
Food waste	68		5
Others	11	19	14

1.3 Olusosun SWDS

LAWMA currently operates 3 dumpsites; Olusosun, Solus and Abule-Egba. The focus of this work is the Olusosun SWDS which is the largest in Lagos. It is the only one fit to host an LFGTE project because it has a remaining life span left of more than 10 years, it receives a large amount of waste and, has the right depth. It was constructed under a World Bank loan secured in 1988 to use the trench system. It is at 60m above sea level and lies on a high density clay deposit under which there are two water aquifers (Bamgbose *et al.*, 2000). The average daily tonnage received in Olusosun between March and June 2004 is given in the Table 2.

Table 2: Average daily tonnage of refuse received at Olusosun site between March and June 2004 (Source: LAWMA)

Type of waste		Mon.	Tues	Wed.	Thurs	Fri	Sat	Sun	Weekly Averages
Domestic Waste	LAWMA	730	850	890	820	815	1130	610	835
	Local Government Sanitation Agencies	150	135	150	210	100	2665	60	
	Private Collectors	1340	1325	1215	1360	1220	1610	1140	
Commercial waste (from markets, non-hazardous waste from institutions etc)	LAWMA	220	190	210	170	180	130	180	835
Total domestic and commercial waste		2440	2500	2465	2560	2315	5535	1990	2829.29
Industrial waste and metal scraps	LAWMA, NAFDAC and SON	230	250	270	225	220	250	270	245.0

Results and Discussion

The focus of the analysis is the assessment of the viability of a LFGTE plant in Olusosun SWDS in Lagos. This is done in two stages. First an analysis of the technical viability as determined by the availability of the methane resource is conducted, followed by a socio economic analysis of the project's survivability. Relevant factors and their interactions in each of these stages are first depicted in Causal Loop Diagrams (CLD), then the results of the STELLA analysis for that stage is presented along with the assumptions under which they were made. The model takes a modular design. The full structure and description of model can be obtained from Aboyade (2004).

1.4 Assessment of Resource Potential

The major factors affecting LFG and hence CH_4 emissions from MSW are mainly the amount of waste generated, the composition of the waste, the conditions under which the waste is disposed, and the climate of the region under study. All the factors, save the last, are dependent one way or the other on the socio-economic characteristics of the region. The CLD in Figure 2 captures the interactions that affect CH_4 emissions from MSW in Lagos.

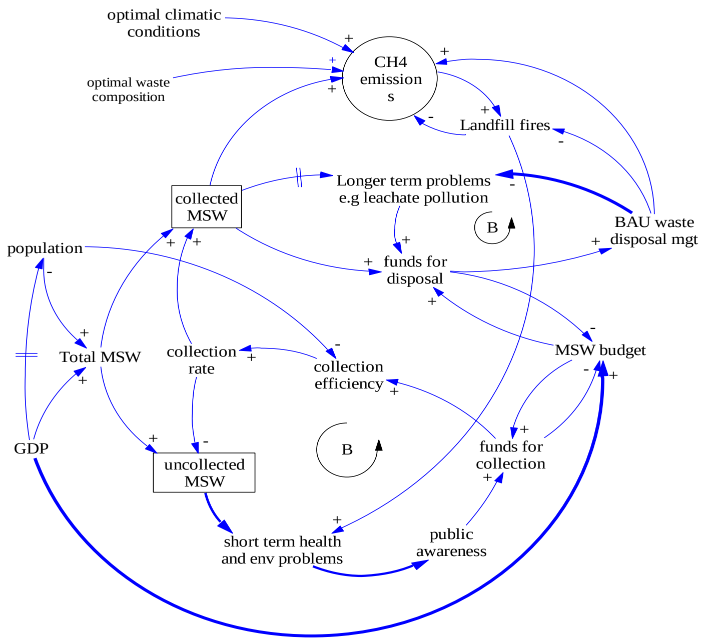

Figure 2: CLD showing factors affecting CH_4 emission from MSW disposal sites

The generated waste is either collected or littered as shown in the CLD. The amount of waste collected depends basically on the collection efficiency of LAWMA as dictated by its own administrative effectiveness, which in the past years has been poor. Where littered waste gets to the point where it becomes aesthetically unpleasant, and presents directly perceptible dangers to public health, public awareness influences government to increase the flow of funds for collection services. Such increase is of course limited by the municipality's budget which in itself is a direct function of the economic prosperity of the state. The poor economic status coupled with the low quality management enjoyed in public services ensures that such increased effort at collection services is hardly sustained. Usually however the limited successes of such efforts at least in reducing the amount of littered waste soon causes public pressure to relax. Also the ever increasing quantities of waste coupled with lack of sustained political will and increasing administrative inefficiencies ensures that the collection rates soon drops and uncleared waste again begins to mount. Interestingly, according to officials in LAWMA, this cycle (represented by the balancing loop in the CLD) very often coincides with the election or appointment of new leaders in the state. This is because in a bid to impress its constituents, the new administration (usually military controlled) pumps money towards reducing the amount of littered waste, only to relax after a while for the same reasons aforementioned.

1.4.1 Methane emissions from Olusosun SWDS

The results of the emission modeling for methane are as shown in the Figure 3 under the following assumptions:

- L_o – Methane generation potential (estimated using the formula, $MFC \times DOC \times DOC_F \times {}^{16}/_{12}$ to be equal to 150m^3/mg). A conservative estimate when compared with 190m^3/Mg for Brazil which has a similar waste composition (Mailly, 2004).
- K- methane generation constant for lack of data is assumed to be the default suggested by IPCC - 0.05

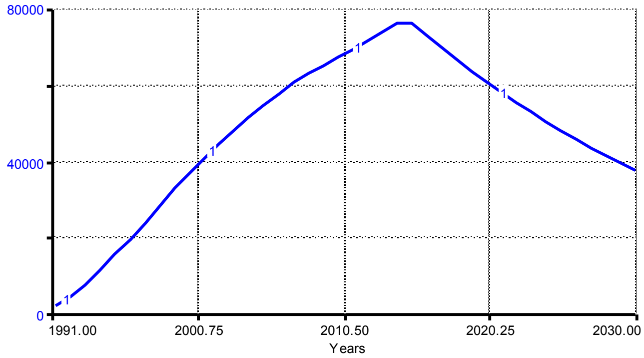

Figure 3: Methane emissions from Olusosun SWDS

The graph shows methane emission from Olusosun reaching its peak of about 76,000 tonnes of methane in 2014 thereabouts with an average annual emission of 63,000 tonnes during the project's lifetime. It also shows that Olusosun will still be generating emissions well beyond 2030. A sensitivity analysis varying k and Lo by ±15% shows that this varies from a low of 47,000 tonnes to a high of 78,000 tonnes CH_4.

1.5 Assessment of Economic Viability

The economic viability of the proposed project is governed by policies in three different sectors; the MSW, energy and climate or emissions trading sectors. MSW policy and practices especially regarding, MSW collection efficiencies, choice of disposal method and so on are crucial to the waste stream which in turn forms the resource for LFG and electricity production. Energy policies relevant to the electricity prices and the level of regulation of electricity sales will to a large extent will ascertain how much income is to be expected from electricity generated from the site. Furthermore, the existence or not of a climate policy is important to determine if CER's can be sold. Economic viability as measured by net present value (NPV) and internal rate of return (IRR) is a direct consequence of the costs associated with the project and revenues accruing to it; all other factors that affect the projects viability e.g electricity price, CER price and interest rates could be said to feed in through these two components.

1.5.1 Assumptions

Cost estimates for this analysis both capital and operational were obtained from representative estimates given in the US EPA's landfill gas-to-energy project development handbook (EPA, 1996). Apart from these, other important cost items are the transaction costs associated with CER sales; monitoring costs, verification and validation costs as well as registration and approval costs. Taking into account the value of emission reductions possible from this project (25 million tCO_2e over a 20 year crediting period) this project would qualify as a very large CDM project (UNFCCC, 2004) and according to Krey & Welt-Wirtschafts-Archiv (2004), the transaction costs associated with registering and validating emissions from the project under the CDM would be about US$0.123/ tCO_2e.

The revenue stream derives mainly from electricity and CER sales. In general it is assumed that the electricity generated from the project would be sold to the municipality for street lighting. Electricity prices in the analysis will be varied according to current obtainable rates. CER prices have typically been within the 3 to 6US$/t$CO_2$e range (Haites & Seres, 2004). Project lifetime of 20 years as consistent with projects of this nature (US EPA, 1999), and tax rate on all profits of 30% which is the prevalent corporate tax rate in Nigeria (NIPC, 2004). The analysis includes capital costs in the year they are incurred and as such it was not necessary to include depreciation (Barish, 1962).

Cash flow analysis of the viability of the project was done under three scenarios: a) Funding from local sources at current discount rates. b) Funding from foreign sources such as the World Banks Carbon Fund. c) Flaring only option (no electricity generated). The major distinguishing factor between the first two scenarios is the cost of capital for the project as determined by interest and discount rates. According to Barish (1962), high interest rates is one major impediment to project finance in developing countries.

1.5.2 Scenario 1: Local funding

Consultations with officials from the state ministry of environment revealed that the government is investigating the possibilities of handing over operation of the landfills to private interests. This scenario simulates the project viability assuming the new private owner decides to borrow from local banks to implement the project. Interest rates in local financial institutions are pegged to the Central Bank's minimum discount rate for treasury bills which is set at 18%. In this scenario it is assumed the local investor borrows from local banks at 22.5% interest.

Putting all these parameters in the STELLA model yield the following results for NPV of the project after 21 years:

Table 3: NPV (in US$) under different CER and electricity price ranges

		Electricity prices US$/MWh		
		21	**50**	**65**
CER price (US$)	0.00	-1,595,909.44	-874,063.87	-498,834.31
	3.00	-1,004,164.81	-279,299.14	95,631.38
	6.00	-384,284.00	340,581.67	715,512.19

Results show that the project cannot be viable under the price regimes given in the table, without additional revenue from CER's. The prices selected in the Table 6 are based on different assumptions under which electricity price for the project could be negotiated. US$21 is the lowest price for which the national utility (Power Holding Company of Nigeria – PHCN) sells to its customers, US$50 is the highest PHCN buys from IPP and US$65 is the price municipalities pay for electricity for street lighting (all per MWh). Personal communication with PHCN officials revealed it is unlikely for PHCN to buy at higher price that US$50/MWh given its recent attempts at commercialization. Even assuming that price could be negotiated, the project still isn't viable when CER's are sold for US$3 as the project still returns a negative NPV. Also the IRR in this case is 13.5% which is clearly below local interest rates. The table shows the project can only be viable (i.e. returns positive NPV) at CER price of up to US$6. Then IRR is at 23%, still too close to the interest rates.

1.5.3 Scenario 2 foreign funding

In the general, the cost of funds from foreign sources are cheaper than that from local sources especially in Nigeria where interest rates are generally on the high side. This is especially true when the sources of the funds are public or non profit institutions, or specialized funds like the World Bank's Carbon Fund. In this scenario a simplified assumption that the project is funded at 8% interest rates yield the following

Table 4: NPV (in US$) under different CER and electricity price ranges with 8% interest rates

		Electricity prices US$/MWh		
		21	**50**	**65**
CER price (US$)	0.00	-9,019,252.88	-3,366,784.37	-443,093.76
	3.00	-4,217,324.06	1,435,144.45	4,358,835.06
	6.00	736,240.20	6,442,369.50	9,366,060.11

Even here it is still obvious that the project cannot break even without additional revenue from CER's during the stipulated project life. However with IRR raging between 12 to 13%, i.e about 5% higher than the cost of funds, represented here by the interest rates, one can argue that the project stand a much better chance of been profitable under this scenario.

1.5.4 Scenario 3 Flaring Only

Further analysis of the first two scenarios point to the fact that CERs makes up between 35% to 53% of revenues depending on whether it is sold for US$3 or US$6. The fact that CER revenues account for so much of the total is combined with the fact that the energy generation part of the costs actually accounts for 67% of the projects capital costs and 90% of the operation and maintenance costs suggests higher rates of return if the project is run without electricity generation. Under this scenario therefore, the project's capital costs is reduced to US$6,354,000 and maintenance costs to US$299,000. This then yields an IRR of about 27% when CERs are sold for US$3 per tCO_2e. This implies the project has much higher returns even when the source of funding is local. This result in essence shows that the most commonly touted direct benefit of LFG capture – energy generation – holds little prospect as a driving force for such an intervention in Nigeria.

Conclusions

The result of this study has shown that the cost of the local private funding is too high to allow the reasonable rate of return for a LFGTE project. Funding from foreign sources at lower lending rates increases the chances of the project being viable, but even that would be by only a slight margin. The flaring only option, without electricity generation on the other hand is the best scenario, as the bulk of the projects revenues are from CER sales. This is just as well, considering that electricity generated from the project will not be able to compete with conventional sources because the costs at which electricity from LFG is produced (approx. US$50/MWh) is slightly higher than the marginal cost for which electricity from natural gas will be produced in the long term (US$39/MWh). This conclusion is not very different from that arising from similar studies in countries where electricity prices are low.

References

Agunwamba, J. (1998). Solid waste management in Nigeria: problems and issues. *Environmental Management*, *22*(6), 849–856.

Bamgbose, O. A., Arowolo, T. A., Oresanya, O., & Yusuf, A. A. (2000). Assessment of Urban Solid Waste Management Practices in Lagos, Nigeria. *African Scientist*, *1*(1), 23-31.

Barish, N. N. (1962). *Economic Analysis for Engineering and Managerial Decision-Making* (Later Printing.). McGraw Hill Book Co.

Bossel, H. (1994). *Modeling and Simulation*. A K Peters/CRC Press.

Cygnet Services Limited. (2002). *Technical and Commercial Proposal for Management of Olusosun Landfill Site*. Lagos: Lagos State Ministry of Environment.

Ellis, J., Corfee-Morlot, J., & Winkler, H. (2004). Taking stock of progress under the Clean Development Mechanism (CDM). *Organisation for Economic Co-operation and Development, Paris*.

EPA, U. (1996). Turning a Liability into as asset: A Landfill Gas-to-energy Project Development Handbook. *USA Environmental Protection Angency-EPA*.

Haites, E., & Seres, S. (2004). Estimating the market potential for the clean development mechanism: review of models and lessons learned. *PCFplus Report*, *19*.

Krey, M., & Welt-Wirtschafts-Archiv, H. (2004). *Transaction costs of CDM projects in India: An empirical survey*. Hamburgisches Welt-Wirtschafts-Archiv (HWWA).

World Bank, B. (2004). The World Bank handbook for the preparation of landfill gas to energy projects in Latin America and the Caribbean. *Waterloo, Ontario*.

Rushbrook, P., Pugh, M., & Mundial, B. (1999). *Solid waste landfills in middle-and lower-income countries: a technical guide to planning, Design, and operation*. Banco Mundial.

Ruth, M., & Hannon, B. (1997). *Modeling Dynamic Economic Systems* (1st ed.). Springer.

Sterman, J. D. (2000). Business dynamics: systems thinking and modeling for a complex world. 2000. *Boston et al: Irwin McGraw-Hill*, *110*.

UNFCCC. (2004). Approved baseline methodology AM0003: Simplified Financial Analysis for Landfill Gas Capture Projects. UNFCCC.

Villavicencio, A. (2003). *A systems view of sustainable energy development*. Discussion Paper. Quito.

Watson, R. T. (2001). IPCC Third Assessment Report: Climate Change 2001: Synthesis report. IPCC.