The Potential for Climate Change Mitigation in the Nigerian Solid Waste Disposal Sector:

A Case Study from Lagos

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Abstract

Solid waste disposal sites account for up to 20% of global emissions of methane the second most significant greenhouse gas. This need not happen as under proper management landfills can in fact have a positive carbon balance. However such management entails the capture and destruction of methane gas emitted from these landfills, an undertaking that has been too costly for many developing countries to implement. The Clean Development Mechanism (CDM) is one of the three emissions trading schemes under the Kyoto protocol that allows investors from developed countries invest in emission reduction projects in developing countries that contribute to their sustainable development. Methane capture from landfills is one of such projects. It, in fact, now account for about 22% of proposed CDM projects so far in countries like India, Brazil and Indonesia. Its popularity can easily be explained by its very obvious potential benefits – improved sanitation, renewable energy generation and the fact that methane has a global warming potential 21 times that of CO_2. This thesis attempts to assess the potential for implementing such a project in te Olusosun waste disposal site in Lagos, Nigeria . Data regarding MSW regulations, its generation rate and composition, as well as data regarding relevant aspects of the Nigerian energy market and its regulations and Nigeria's climate change policies are evaluated in order to determine the potential for successful implementation of a Landfill gas to energy project in the Olusosun dumpsite in Lagos, Nigeria.

System dynamics was used to model the interactions within the three main sectors that will affect the projects performance, waste, energy and climate. The project viability as determined by its Net Present Value and Internal Rate of return was evaluated under three scenarios: first scenario depicts a situation where the project is funded by local private sources, second scenario presumes, project funding is received from foreign sources with lower interest rates. The last scenario assumes that the no electricity is generated from recovered methane, instead, the all recovered gas is flared. The results of the analysis showed that the last scenario was the most viable.

Kew words: Climate change, municipal solid waste, greenhouse gases, energy, emissions trading.

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List of abbreviations

^	Nigerian Naira
US$	United States Dollars (I US$ = 100^) Aprroximately
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH_4	Methane
CLD	Causal Loop Diagram
CO_2	Carbon (IV) Oxide
DNA	Designated National authority
EU	European Union
FEPA	Federal Environmental Proctection Agency
FGN	Federal Government of Nigeria
FME	Federal Ministry of Environment
FOD	First Order Decay
GHG	Greenhouse Gases
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel for Climate Change
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature and Natural Resources
LAWMA	Lagos State Waste Management Association
LFG	Landfill Capture
LFGTE	Landfill Gas to Energy
LSG	Lagos State Goverment
MSW	Municipal Solid Waste
NEPA	National Electric Power Authority
NER	National Electric Regulator
NIPC	Nigerian Investment Promotion Commission
NMVOC	Non methane Volatile Organic compaounds
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
SEEDS	State Economic Empowerment and Development Strategy
SWDS	Solid Waste Disposal Sites
tCO_2e	1 tonne CO_2 equivalent
UN	United Nations
UNDP	United Nations Development Fund
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United states Environmental Protection agency
WCED	World Commission for Environment and Development
WDI	World Development Indicators

1 Background

1.1 Introduction

Mounting scientific evidence linking climate change to anthropogenic greenhouse gas (GHG) emissions has given needed boost to the calls for adopting less carbon intensive economic growth (UNFCCC, 1997). Increasing attention is been directed at developing countries where much of such future growths are 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 – or at least pay lip service to the fact – that it would be undesirable for such growth to be sustained at current levels of carbon intensity.

There is general consensus on the need therefore, to integrate climate concerns into sustainable development objectives in all sectors of the economy; energy, transport, agriculture and so on. One generally overlooked sub-sector in this respect is municipal solid waste (MSW) disposal. This sector contributes significantly to global GHG emissions and is a major challenge to public health especially in lower income countries. Where proper management of solid waste disposal sites (SDWS) 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.

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' 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. India, Brazil and China, already have 42 such projects between them at different stages of implementation (Ellis et al, 2004). This is largely possible because such countries have positioned themselves properly, devoting significant attention to the encouragement of such projects and putting in place climate change policies, conducting resource assessment studies and technology needs inventories.

This study aims to determine the prospects of Nigeria also taking advantage of this mechanism particularly in the MSW disposal sector. This is done by focusing on the potential of implementing a viable landfill gas to energy project (for as will be shown later in the report, the predominant method for GHG emissions reduction in MSW management is by the capture of landfill gas (LFG) for either flaring or for conversion to energy) 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.

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1.2 Synopsis

The study objectives as well as, research questions, methodology adopted and limitations of the study will be discussed in the rest of this chapter. The chapter ends with a brief background description of

Nigeria and the city of Lagos in particular, giving an overview of the physical and socio-economic characteristics therein. Chapter two follows with the literature review. Here, salient issues in MSW disposal management as it affects sustainable development and the link to climate change are discussed. A brief introduction is also given to climate change, its causes and the issues that led to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The data and material gathered from field studies are presented in chapter 3 in a descriptive format of the existing state of relevant aspects of MSW management and energy sectors as well as progress under climate change policy implementation in Nigeria. The study results and discussions are presented in chapter 4 and conclusions and recommendations follow in chapter 5.

1.3 Objectives

This study will evaluate the opportunities for climate change mitigation in the MSW disposal sector in Nigeria by assessing the feasibility of a landfill gas capture project in Olusosun solid waste disposal site in Lagos as an example.
In achieving this objective, the following research questions shall be addressed

- What is the level of methane emissions arising from current practices in MSW disposal given the biophysical potentials?
- Is there enough potential to make a LFG recovery project technically viable?
- What are the pertinent regulations and practices in the local, energy and climate sectors and markets that could affect the performance of a landfill gas capture project in the site under study?
- Given these opportunities and constraint, would such an intervention be economically viable?
- Under what scenarios therefore, could the project best be implemented?

1.4 Scope

The scope of the study is as shown in the conceptual map below (Figure 1.1) describes boundaries of the study (the outer black box). Components outside the box are considered outside the boundaries of this study even though it is recognized that they do have influence on interactions within the study for instance, increased recycling and reuse policies will imply less waste gets to disposal sites. Also, the study focuses the use of LFG for flaring and for electricity generation only, the other applications of LFG captured, like heating and as fuel for transport vehicles are only mentioned, but not considered in the analysis. The smaller dotted lined boxes in figure 1.1 represents the various sectors to be analyzed; the blue colored box represents the energy sector, while the green and red boxes represented the climate change and MSW sectors.

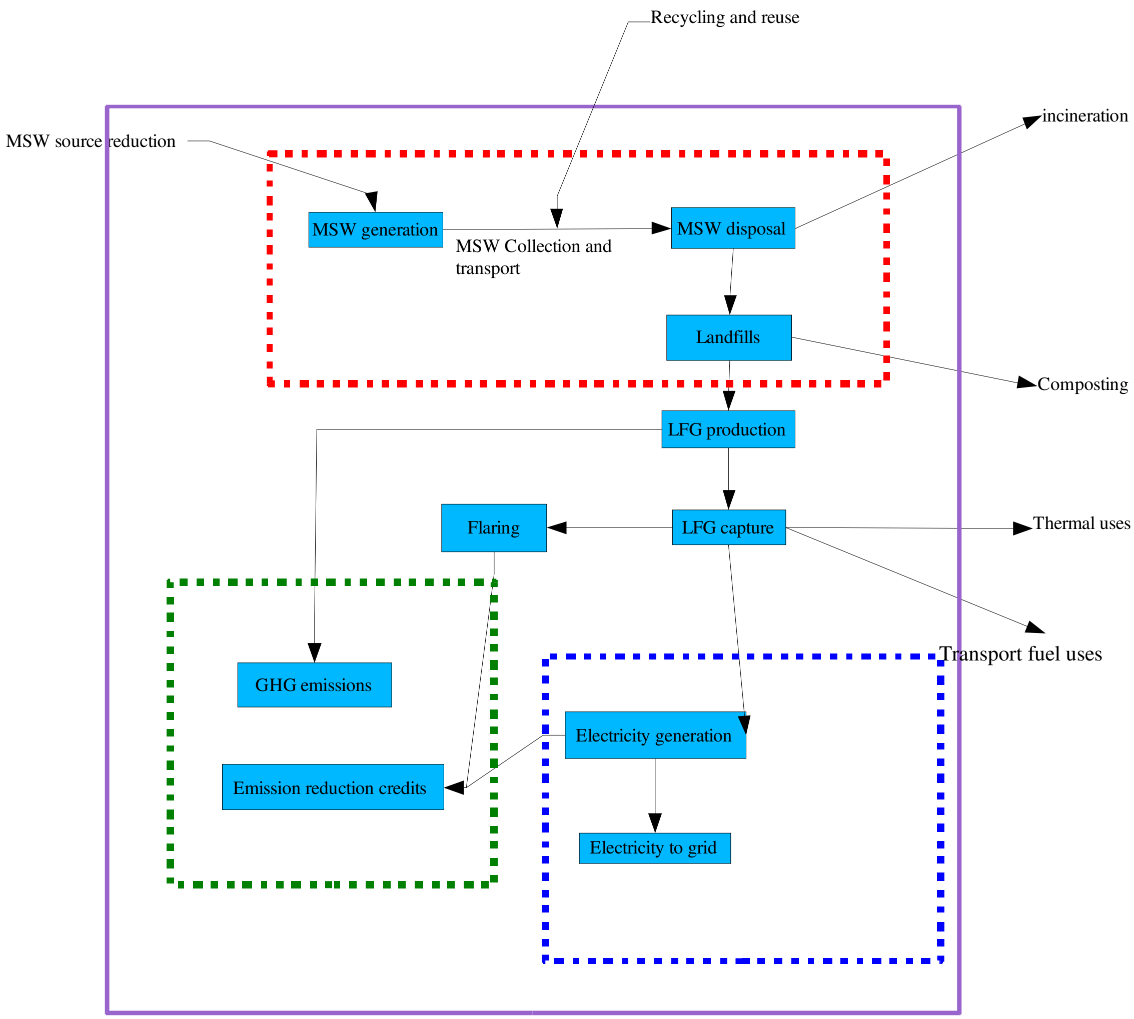

Figure 1.1 Conceptual map showing boundaries of study

1.5 Hypothesis

It is hypothesized that there is enough theoretical potential to make a LFG capture project viable. It is further expected that given current practices and regulations in the energy markets the project would also be economically viable. However, given the low priority given to climate concerns in Nigeria, it is unlikely that such a project would be embarked on without external motivation and spurring.

1.6 Conceptual framework

This thesis is essentially an empirical study that proposes a technological intervention straddling three policy sectors, MSW, energy and climate with clear and established benefits to sustainable development objectives in these sectors. In the MSW sector for instance, LFG capture reduces the impact of disposed MSW on public health[1], in the energy sector, LFG forms a renewable energy source at it contains between 45-65% methane (Bingemer and Crutzen, 1987). Methane is a potent GHG and

[1] LFG capture reduces odour and the risks of fire in the SWDS. It also prolongs the lifetime of the disposal site (Rashbrook and Pugh 1999 p 97)

so reduction in quantities emitted has immense benefits to the climate. The study then goes ahead to assess the extent to which such a project can be successfully implemented in Nigeria by focusing on its implementation on a particular site, Olusosun SWDS in Lagos. In other words the study suggests an established solution for a given problem or set of problems, in this case LFG capture for reducing emissions from waste disposal and tries to determine the extent to which that solution can be feasible in a given context.

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 (Villavicienco, 2004). 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 (See figure 1.2).

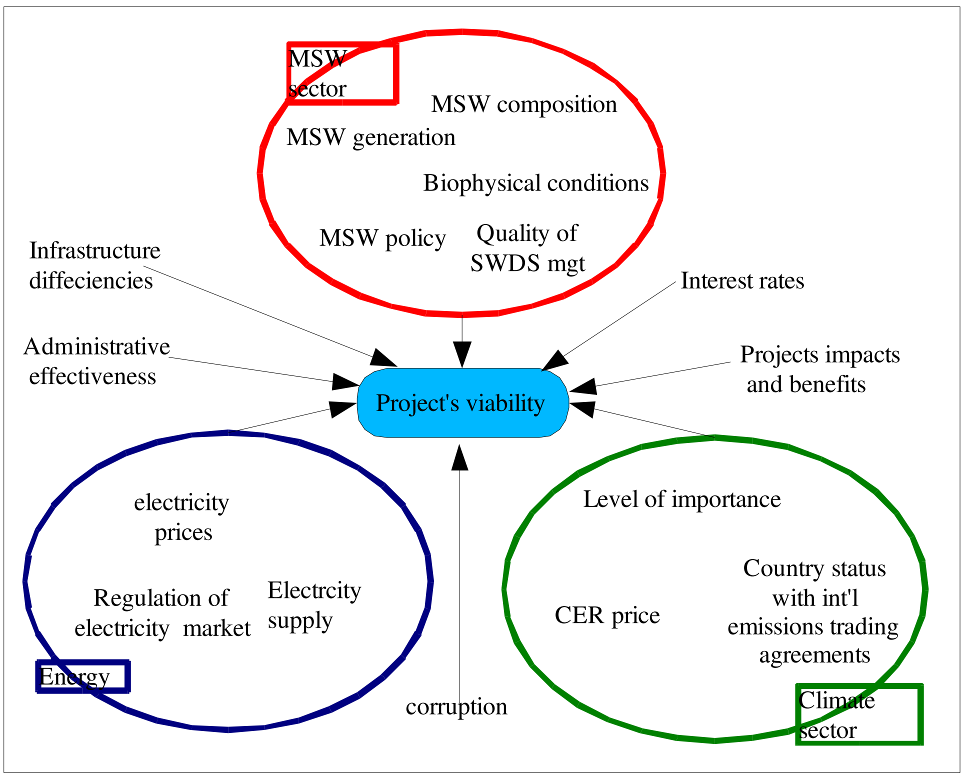

Figure 1.2 Mental model of system structure to be studied

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, 2004 p4) - dynamic, in the sense that the system variables evolve over time as the result of previous interactions (Ruth and Hannon, 1997 p6). 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 theory goes, the system's behavior can then be simulated with reasonable levels of confidence (Bossel, 1994, p8). Various permutations and combinations of the variables can also be simulated and likely outcomes evaluated. System dynamics is here applied in analyzing the sectors shown in the conceptual map above. 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. The next section outlines the study design adopted in this thesis for analyzing such interactions.

1.7 Materials and Methods

The table below gives a more detailed description how the mental model as described above is of materials and methodologies used and how they are applied in the study in answering the research questions. Data was mostly obtained from secondary sources, supported by interviews with officials from the Federal and Lagos State Ministry of environment, and the Lagos State Waste Management Authority LAWMA) and personal observation from site visits.

Table 1.1 Methodology and study design

Research questions	Method of analysis	Data sources	Outcome
What is the level of GHG emissions (especially methane-CH_4) arising from current practices in MSW disposal?	An examination of the institutional structure within the MSW sector and a depiction of the forces at play using a CLD[1] Key drivers as reflected in the CLD are used in a STELLA[2] model in order to generate resultant emission estimates. The revised 1996 IPPC[3] guidelines for National GHG inventories(IPCC, 1996) were adopted in determining emission rates and factors	A description of current waste management practices obtained from government reports, published articles and interviews with officials of the ministry of environment and the Lagos state waste management authority. Data concerning waste characteristics where obtained from Government reports. Where this was inadequate, default values as prescribed by the IPCC guidelines were adopted.	Discussions of the current state of MSW in Lagos, institutional structures. CLD of factors affecting CH_4 emissions form MSW Emissions model in STELLA to give a quantitative estimate of CH_4 in Lagos, and from Olusosun Landfill in particular under different scenarios and a discussion of the results
What is the theoretical potential of generating energy from the waste using LFG to energy technology?	The World Bank's method for assessing potential LFGTE projects as found in the ESMAP LFG manual (World Bank, 2004). Analysis is done also using STELLA	Results of analysis above Literature review	Estimates of potential electricity generation from the STELLA model. Discussion of results. Discussion concerning best potential options for utilizing energy generated.
Would such an intervention be economically viable? Under what conditions?	The World Bank's method for assessing potential LFGTE projects as found in the ESMAP LFG manual (World Bank, 2004). Financial analysis is done also using STELLA	-Government reports, and interviews with energy experts in the Centre for Energy Research and Development, Ife. one of the key centers for energy research in Nigeria. -Estimation of project costs was adopted from representative costs as given in the Landfill Gas-to-Energy Project Development Handbook (US EPA 1996)	Am overview of regulatory environment in the energy sector with a view to determining market access for energy generated from project. Results of financial analysis and discussions of its implications on the viability of the project.

[1] Causal Loop Diagram also called an influence diagram (Bossel 1994)
[2] A system dynamics modeling software developed by High Performance Systems Inc
[3] Intergovernmental Panel for Climate Change

Table 1.1 shows that STELLA will be used for quantitative analysis of data. The IPCC's methodology for estimating GHG emissions are built into the model for emission calculations at the National State and site levels. These IPCC methodologies are explained in better detail in section 2.4.1

1.8 Brief Description of Nigeria

1.8.1 Physical Characteristics

Nigeria is the most populous country in Africa. Its exact population figures are not known but according Nigeria government own's estimate based on the last nationwide census in 1991, the population reached 125 million in 2003 (IIASA[1] and the US census bureau estimated 130 million in 2002). The country also experiences some one of the highest population growth rates in the world (Nigeria's population had more than tripled from 33 million in 1950 to 112 million in 1995 and is projected at present growth rate to reach figure of 339 million by 2050: a ten-fold increase within one century that according to IIASA has no historical precedence). Much of this growth will be in urban areas which currently accounts for 47% of total population, up from 23% in 1975(UNDP, 2004).

Figure 1.3 Map showing location of Nigeria (Source: Shell Nigeria)

Its land area of about 910,000sq km (roughly double the size of Sweden) makes it only the13th largest in Africa implying that its population density is higher than the average. The country lies between 4^0 and 14^0 N latitudes and 3^0 and 13^0 E longitudes. It is bordered by Benin Republic in the west, Niger Republic in the north, Cameroon in the east and the Atlantic Ocean in the south (figure 1.3). Nigeria lies primarily in the lowland humid tropics characterized by high temperatures with low mean variations throughout the year. The temperatures range from 22^{0}C to 30^{0}C.

1.8.2 Socio-Economic characteristics

Nigeria is a country with over 250 different ethnic groups and possesses abundant human and natural resources. Adult literacy levels at 63% are higher than average in developing countries and even higher than the India's' at (57%), and the South Asian average of 56% (WDI, 2000). Natural and mineral resources and potentials including bitumen, coal, gold, tin and iron ore deposits exist in commercial quantities. These resources except for oil and gas have largely been left underutilized. Where they have been harnessed, as is the case with petroleum, the wealth has not been fairly distributed. While about 70% still live under US$2 over $107 billion of Nigerian owned private wealth is kept outside the

[1] International Institute for Applied Systems Analysis, Austria. www.iiasa.ac.at

country (UNIDO, 2004). A fact corroborated by low levels of income distribution: the top 2% received as much income as the bottom 55% in 2000, up from 12% in 1970 (UNIDO, 2004).

Nigeria's economy had always depended on commodity exports, agriculture forming the major part before the 70´s. Discovery of crude oil in the late 60's brought impressive economic growth. GDP grew by 8.8% between 1970 and 1974, caused by massive inflow of foreign exchange from oil earnings as well as high domestic and foreign direct investment in industry, construction and services. Agriculture which used to be the economic mainstay employing over 60% of the labor force was neglected such that its share of GDP output dropped from close to 60% in 1960s to nearly 35% in 1975. The oil industry on the other hand despite the fact that it accounts for nearly all revenues, employs only about 6% of the labour force and now accounts for more than 95% of exports earnings. There was significant explosion in infrastructural development during the period but this couldn't be sustained as the economy began to show distress in late 70s and early 80s with the collapse in international oil prices GDP saw a drop from 7.7% in 1970 to 1977 to 2.2 % in 1978 to 1985. Income per capita also fell from close to US$800 during the oil boom of the late 70s to about US$350 in 2000 (IMF, 2003). However public spending did not slow down proportionately during the period leading to large fiscal deficits. In a bid to finance domestic debt government borrowed heavily and thus increased external debts. Despite the borrowing, the rate of infrastructure improvements could no longer meet rising population demands and urbanization. The quality of public administration followed the same downward trend affecting the provision of utilities and public services such as energy, water and other public infrastructure. Capacity utilization was also affected dropping from in 75% in 1975 to less than 40% in 1995 (CBN, 2004).

Such poor economic performance in the midst of seemingly abundant human and natural resources has been the subject of much study (Santoro,1999; Lawal,1998; IMF, 2003) and most conclude that the problem has been bad leadership. In 1999 the country ended close to 40 years of military rule and political instability with the democratic election and subsequent swearing of the current President, Olusegun Obasanjo. Since his inception, the president has embarked on wide-sweeping reforms aimed at reducing corruption, improving the countries international image and reducing inducing economic growth. Some of these reforms have started yielding fruit as capacity utilization of industries has improved to nearly 60% in 2003. The quality of governance as measured by the world bank has also seen improvements (World Bank, 2004b).

1.8.3 Political Characteristics

The geopolitical entity now known as Nigeria, consisting of about 60 major ethnic groups, was the result of the amalgamation of two British colonies the Northern and Southern Protectorate in 1914. The country gained independence from Britain in 1960 with three major administrative divisions. It now consists of 36 states and a Federal capital territory with a constitution much like that of the United States. Each state, headed by a

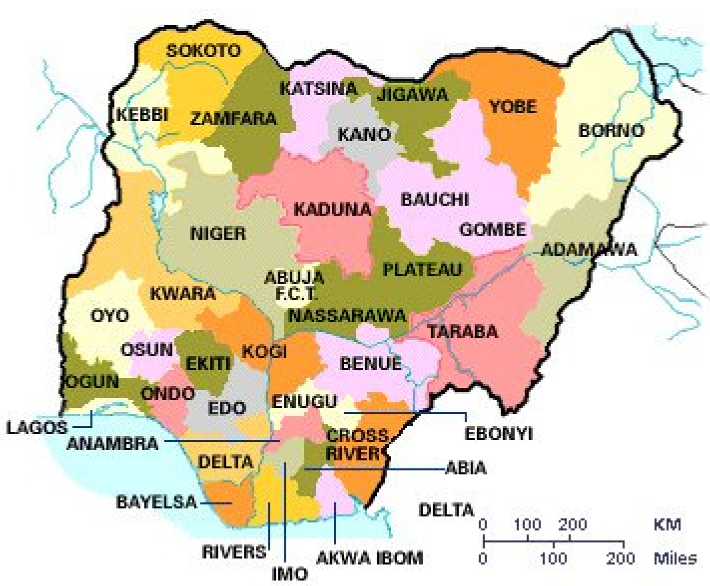

Figure 1.4 Administrative divisions (States) in Nigeria (Source Shell Nigeria)

governor, is further divided into local government areas (LGA).

1.9 Brief Description of Lagos State

Lagos is the economic hub of Nigeria and is its largest city with a population anywhere from 11 million (Nigeria official census figures[1]) to 15 million (UN, World Bank and US Census Bureau estimates[2]). It is currently the 7th largest city in the world, but with current annual growth rates of about 6%-8% (i.e. up to 600,000 persons per annum or 1,644 people daily) it is projected to become the 3rd largest by 2015 (US Census Bureau).

Lagos was originally founded as a trading port in 17th century by the Portuguese and became colonial administrative headquarters of the newly formed Nigeria in 1914 and remained as capital even after independence 1960 and until 1990 when a new federal capital territory was built in Abuja. It is the smallest of the administrative states in the country (see figure 1.4) in terms of land area occupying only 3577sq km of mostly coastal plains (UN habitat).

The state is surrounded by water lagoons which make up about 22% of the land mass. Metropolitan Lagos itself accounts for only 37% of the states land area, but is occupied by more than 80% of the states population, such that population densities in the metropolis reaches up to 20,000 persons per sq km (Lagos State Government, 2004). Such high densities combined with inadequate funding and poor management has lead to infrastructure decay on massive scales. The city simply can't afford any major improvements in its infrastructure given its current budget of about US$500 million meant to cater for its approximately 15 million people, an sum only one third of Johannesburg's budget of US$1.2 billion (Okunola, 2002) where the population is 2.5 million and almost one fourth of Malmo's budget of US$1.74 billion where population is a mere 266,000[3].

There are 57 local government areas in Lagos each headed by a democratically elected council under the coordination of the state governor. Since the metropolis spans across many councils, municipal services are actually carried out by central bodies e.g. the Lagos State Water Corporation (LSWC), the Lagos State Transport Management Agency (LASTMA) and the Lagos State Waste Management Authority (LAWMA).

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[1] obtained from www.nigeria.gov.ng

[2] obtained from (UN, 1999; http://www.worldbank.org/data/dataquery.html, and www.census.gov/ipc/www/world.html respectively)

[3] Obtained from www.malmo.se

2 Explanation of Central Concepts and literature review

This chapter contains an explanation of the central concepts used in this report. These concepts are climate change, sustainable development, MSW management, LFG capture and utilization. A review of applications of system dynamics on the climate change dimensions of MSW management is also given.

2.1 Climate Change background

Anthropogenic climate change is caused by the increase in the quantities of green house gases (GHGs) in the atmosphere as a result of various human activities. GHGs the most important of which are - carbon (IV) oxide (CO_2), methane (CH_4), dinitrogen-oxide (N_2O), hydrofluorocarbons(HFC), perfluorocarbons-(PFC) and sulphur-hexafluoride(SF) - are otherwise naturally occurring atmospheric gases which performs the function of keeping the earth warm by trapping the sun's heat. But their increased concentration caused by human actions has been shown to intensify this natural effect causing significant unnatural temperature changes in the earth's temperature. Such temperature changes have been discovered could lead to major disturbances to the ecosystem: sea level rise and the flooding of low level plains, drought, and increased frequencies of floods, and other weather related natural disasters are likely to occur in various parts of the world putting millions at risk (IPCC, 1996).

CO_2 is by far the most significant GHG as it is released from nearly all human activity that has contributed to the economic growth witnessed in the past century, especially transport, industry and agriculture. Methane, the next most significant in terms of quantity is mostly emitted from anaerobic degradation of organic waste, the burning of biomass and natural gas leakage (Bingemer and Crutzen, 1987).

Historically developed countries have been largely responsible for the bulk of these emissions as the activities that lead to it, industry and transport – are found with the highest intensities in these countries (see figure 2.1).

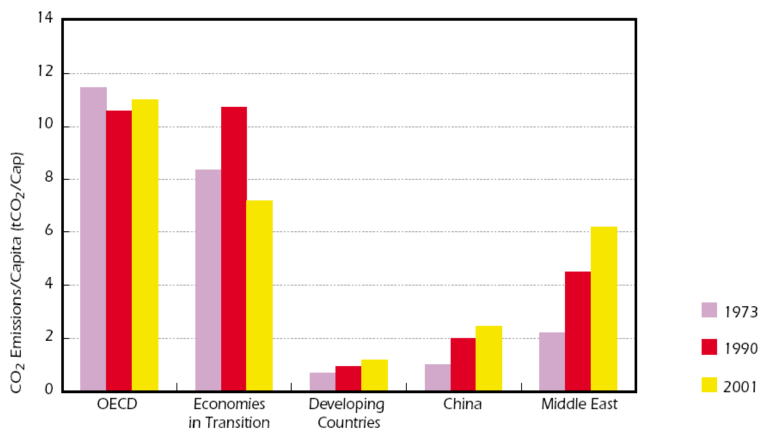

Figure 2.1 CO2 emissions per capita 1973, 1990 and 2001 : Unander F. (2003)

In a bid to better understand the climate change phenomena and its implications, the WMO[1] and UNEP[2] in 1988 set up the Intergovernmental Panel for Climate Change (IPCC) composed of scientists and academics, as well of official government representatives, with a mandate to study the phenomenon and give appropriate advice on its implications to the participating governments (Weart, 2003). Their first report – the FAR (First Assessment Report) released in 1990 established that the

[1] World Meteorological Organization
[2] United Nations Environmental Program

earth had indeed been warming. The report was significant enough to form the basis for the United Nations Framework United Nations Framework Convention on Climate Change (UNFCCC) signed by 150 countries at the First Earth Summit[1] in Rio in 1992. The second and third assessments reports (SAR and TAR) gave stronger evidence of the link between global warming and GHG emissions. These later reports led the Conference of Parties[2] (COP) at its third conference in 1997 at Kyoto, Japan to form what is known as the Kyoto Protocol. The Protocol is legally binding set of obligations for 38 industrialized countries and 11 countries in Central and Eastern Europe to return their GHG emissions to 5.2% below the 1990 levels (UNFCCC, 1997).

2.2 Climate change mitigation in the context of Sustainable Development

The term sustainable development, originally used by the International Union for Conservation of Nature and Natural Resources (IUCN, 1980) in their publication; 'World Conservation Strategy; Living Resources Conservation for Sustainable Development' was made popular seven years later by popular Brundtland's[3] Report (Nellissen et al 1997 pp 262). The Report defined sustainable development as "…development that meets the need of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Inherent in the definition are the broad principles of intergenerational and intragenerational equity. The intergenerational equity implication of the sustainable development concept is pretty straightforward and has been the focus of much international discourse. Pearce et al (1990) suggested that it implies that welfare allocation to future generations must not fall over time, in contrast to conventional theories of economic growth which discounts the welfare of future generations in the allocation of resources for optimal economic growth (Halnæs and Markandya, 2002 pp 17).

On the other hand, the intragenerational equity objective of sustainable development as it concerns climate change would imply that industrialized countries should bear the cost of climate change mitigation as they have been largely responsible for GHG emissions that are causing it (UNFCCC 1992). It also implies that they should do more to help poor countries who are ironically more vulnerable, to adapt to consequences of global warming. This is no doubt a politically sensitive notion whose implementation will be faces with all sorts of potential conflicts (Carter, 2001 p127) as the quote below aptly reflects:

"Many, if not most economists would subscribe to the view that intergenerational equity is probably good ……… But if these same economists were faced with a vote on whether we ought to go ahead with an equivalent program of intragenerational equity and transfer resources from the rich to the poor until equalization occurred, very few indeed would vote for such a program if they thought it had any chance of passing." (O'Riordan, T. and Jaeger, J. (1996) Politics Of Climate Change: A European Perspective, Routledge, London. Taken from Ryner and Malone, 2001)

Developed countries may have contributed most to GHG emissions in the past. The fact is however, that if present trends in population growth rates and fossil –fuel based industrialization continues, emissions from what are now referred to as developing countries will soon catch up with and overtake those from developing countries as can be seen from chart above (figure 2.1).

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[1] Formally called the United Nations Conference on Environment and Development (UNCED)
[2] Established in the convention as the body responsible for monitoring progress towards emission reductions
[3] The report was commissioned by World Commission on Environment and Development but is more commonly referred to as the Brundtland's Report

This knowledge has led to the increasing attempts on both international, national and research arenas in developing policies integrating sustainable development requirement into climate change mitigation activities. For in theory, reducing GHG emissions need not lead to reduced economic growth. Some impacts of GHG mitigation activities such as increased energy efficiency and reduced local air pollution is significant to local economies. Besides sound sustainable development policies that ordinarily where not intended as climate change mitigation projects like sustainable forestry and integrated waste management practices also tend to reduce GHG emissions rates. It has therefore been argued that climate change mitigation need not be a burden but could potentially reinforce sustainable development strategies (Halnæs and Markandya, 2002)

2.3 Kyoto Protocol and CDM

In the spirit of integrating climate change policies into the sustainable development objectives of developing countries and pursuing the sustainable development objectives of intragenerational equity, the UNFCCC Kyoto's protocol established the Clean Development Mechanism (CDM) under Article 12 as one of the three mechanisms for emission reduction. An excerpt of the Protocol text reads:

" …The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3…".(UNFCCC 1997).

CDM was initiated as one of three cooperative mechanisms instituted by the Kyoto Protocol; the other two being International Emissions Trading[1] and the Joint Implementation[2] (JI) under which emissions could be traded. JI and IETA. The rationale behind emissions trading being that the cost of mitigating GHG emissions is generally lower in developing countries than in developed countries.(UNEP, 2004) coupled with the fact that GHG emissions have the same effect on the climate irrespective of where they are emitted (IPCC, 1996).

The Kyoto Protocol was adopted in December 1997 but its coming into force requires that at least 55 of Annex I parties accounting for 55% of global GHG emissions at 1990 levels must first ratify. According to the UNFCCC's website, there are currently 33 Annex 1 Parties (i.e. countries) with emissions amounting up to 44.2% that have ratified the protocol. The United states pulled out of the Protocol so it can only come into force if Russia ratifies. Russia accounts for 17.4% of total 1990 emission and will bring emissions levels to 61.6% should it decide to ratify. As at the time of writing this report, the government have sent their ratification documents the UNFCCC secretariat (UNFCCC News, October 2004).

In order for countries to participate in the CDM they must meet some basic requirements: they must have ratified the protocol and must establish a National CDM authority called the Designated National Authority (DNA). Industrialized countries in addition must have a national system for the estimation of GHGs, a national registry and an accounting system for the sale and purchase of emission reductions among other things (UNEP, 2004 pp. 13). The Protocol's conditions for prospective CDM projects

[1] International Trading Agreements permits countries to transfer parts of their allowed emissions (UNEP, 2004).
[2] JI: Allows countries to claim emission reduction gained from investment in other industrialized countries (UNEP, 2004)

must satisfy two criteria of additionality and sustainable development. Additionality according to the Kyoto protocol means that the CDM project must lead to 'certified emission reductions' (CERs) that normally wouldn't have occurred without the project. A CER refers one tonne of avoided CO_2e[1] that has been certified after validation by an independent third party. Sustainable development criteria simply restates the purpose of CDM in the first place which is to assist non-Annex 1 countries achieve sustainable development in the context of climate change (*ibid.*). The sustainable development criteria are further classified into social, economic and environmental criteria in conformity with conventional sustainable development objectives.

Already significant progress has been made in CDM, out of 124 countries that have ratified, approved, accepted or acceded to the Kyoto protocol, a recent study (Ellis et al, 2004) reported that 57 countries had designated a DNA, 48 of which are non-Annex I countries. Up to 160 emissions reduction projects are at various stages of planning and implementation. Approximately 32 Mt CO_2e/year is the expected GHG reduction from these activities. These activities have mostly been in renewable energy, methane emission reduction and Flue gas decomposition. CDM through such projects provides a platform for developing countries to benefit from the transfer of technology and financial resources, income generation and increased employment opportunities and sustainable ways of energy production.

2.4 MSW management in the context of climate change

Ackerman (2000) identified five predominantly ways in which solid waste management impacts on climate change: reduction in industrial energy use due to recycling and source reduction. "landfill methane emissions, energy recovery from waste to displace fossil based electricity from grid, carbon based sequestration due to decreased demand for virgin paper and energy used in long-distance transport of waste" (p223).

From a sustainability point of view, waste disposal is the least preferred option in waste management because it is essentially an end of pipe solution and it has the most impact on the environment (Seuss 1985). Despite this fact, the bulk of MSW still finds its way into solid waste disposal sites(SWDS) all over the world - 60% in the EU and a little less than that in the US (Smith et al 2001; US EPA, 2002; Bingemer and Crutzen, 1987) - as it still is one of the least complicated ways of handling waste in terms of technical expertise and costs. The proportion of MSW that goes to disposal sites is likely to be higher in developing countries because they have less recycling and reuse capabilities. What this says is that, regardless of the fact that landfills are least preferred options for sustainable MSW management, trends show that they will still be around for quite a while. Especially in developing countries where MSW management is still at the stage where only the effective collection of MSW away from the streets into disposal sites are considered accomplishments which stil eludes many municipalities in developing countries. Many of such countries spend remarkably less on collection systems than they do on improving recycling and reuse programs.

Such continued dependence on SWDS has its ramifications as they not only pose local health and environmental problems but global ones as well, in that, they serve as a significant source of GHG emissions especially methane. For instance an EU study showed that landfilling accounts for about a

[1] CO_2e (CO_2 equivalent) is the unit of measurement to indicate global warming potentials of various GHG in CO_2 terms. Eg. a tonne of methane = 21 tonnes CO_2e because the global warming potential of methane is 21 times that of CO_2

third of total anthropogenic emissions of CH_4 in the region. A separate US study also reveals that landfills are the largest anthropogenic source of methane-CH_4 in the US. Globally waste is estimated to be responsible for anywhere up to 20% of global methane emissions with MSW representing about 90% of it (Bingemer and Crutzen, 1987; IPCC, 1992; Thorneloe el al, 2002).

Hence the potential for reducing CH4 emissions in the waste sector lies primarily with landfills and dumpsites. Mitigating climate change therefore implies increased efforts in the proper operation of landfills in such a way as to make them more ‘climate friendly’. This is basically done by collecting emitted LFG from the disposal sites and either flaring it, or utilizing it as an energy resource for heating or for electricity production, a process referred to as Landfill Gas to Energy (LFGTE) which would be described in the next section.

It is worthy to mention the fact that according to some studies, when properly maintained will actually have a positive impact on the carbon balance. Unlike incineration for instance which results in the rapid oxidation of organic matter, landfills serves as sinks for the long term accumulation of such materials, much like natural peatlands (Bramryd, 1997).

2.4.1 The LFGTE process

2.4.2 LFG Generation

Methane (CH_4) emissions from disposed MSW are as a result of anaerobic biodegradation of organic waste. When large amounts of waste are dumped on the same spot, oxygen availability declines creating favourable conditions for anaerobic bacteria to act on the waste, decomposing it to produce compounds like amino acids, sugars and fatty acids which are further broken down to H_2, CO_2, COOH, HCOOH and CH3OH. These substances form the substrate which methanogenic bacteria works on to produce what is known as biogas or landfill gas(LFG) - a combustible gas which consists mainly of CH_4 (Bingemer and Crutzen 1987).

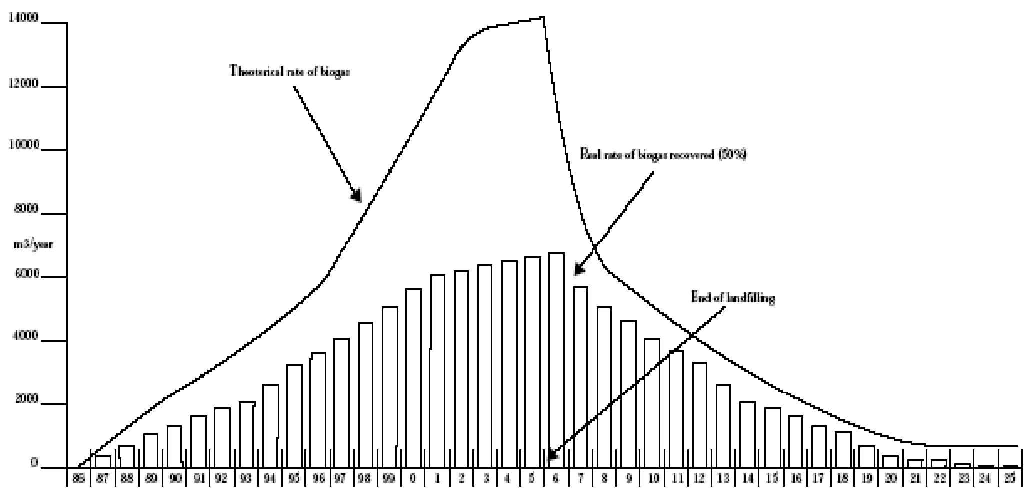

Figure 2.2 Fate of LFG Production over time (Source: M E Fernandez et al 1995)

Various conditions govern the rate of LFG generation from any site. The most important are waste composition, operation and management of the disposal site and physical conditions of location of the site. Waste composition is regarded as the most important factor affecting LFG production in any site; LFG generation is a microbial process dependent on the organic content of the waste. Studies show that the methane generation potential of waste ranges from 0 for inorganic waste, to over 200m3/tonne for MSW with large proportions of organic waste (IPCC, 1996). Moisture content is important because it affects the rate of decomposition of the waste and is itself dependent of other factors such as rainfall characteristics of the location, the extent of infiltration from surface and groundwater, and the volume of water produced during decomposition. The generation of LFG over time usually is depicted by the chart above. (fig 2.2)

2.4.2.1 Estimation methods for methane for SWDS

Many methods and models have been developed for projecting LFG generation potential from SDWS. The IPCC recommends two of these methods for LFG generation estimation for the purpose of establishing national GHG inventories.

2.4.2.1.1 Default Methodology

The first one and also the simpler one is the default methodology (Teir 1) adapted from the theoretical gas yield methodology developed by Bingemer and Crutzen (1987). It is based on the assumption that all potential CH4 is released in the same year the waste was deposited, which is not really the case (see fig 2.2). This method is recommended for regions where more detailed data on waste is not available(IPCC 1996). Its variables include estimates of degradable organic carbon content of the waste, and the quality of management of the disposal site. Under this method methane emissions are calculated using the equation:

Methane emissions (Gg/yr)**=**
$$(MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1-OX)$$
where:

MSW_T = total MSW generated (Gg/yr) and can be caculated by multiplying the population with annual MSW generation
MSW_F = fraction of MSW disposed to solid waste disposal sites
MCF = methane correction factor (fraction). This variable reflects the condition of the disposal site. It ranges from 0.4 for shallow unmanaged sites to 1.0 for managed site above 5m deep.
DOC = degradable organic carbon (fraction) It can be calculated for any region using waste composition data for that region in the formular
Per cent DOC (by weight) = 0.4 (A) + 0.17 (B) + 0.15 (C) + 0.30 (D)
Where A = per cent MSW that is paper and textiles
B = per cent MSW that is garden waste, park waste or other non-food organic putrescibles
C = per cent MSW that is food waste
D = per cent MSW that is wood or straw

DOC_F = fraction DOC dissimilated. This represents the portion of DOC that is actually converted to gas. It is determined by the equation 0.014T+ 0.28 where T is the temperature of the site. The default value according to the revised 1996 IPCC guidelines is 0.77. This figure has been revised downwards in the more recent Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories(IPCC 2000) to 0.5 and that was what was used in this study.
F = fraction of CH4 in landfill gas (default is 0.5)

R = recovered $CH4$ (Gg/yr)
OX = oxidation factor (fraction - default is 0)

The default method is recommended by the IPCC for the estimation of country and regional emissions.

2.4.2.1.2 First Order Decay Methodology

The second, more complex and more accurate methodology is the first order kinetic methodology (also called the Scholl-Canyon Model). It is more suited to calculating emission from individual disposal sites as it predicts LFG generation over the lifetime of a site using site specific inputs. It is given by the equation:

Methane generated in current year Q (m^3/yr) = $\mathbf{L_0\ R\ (e^{-kc} - e^{-kt})}$
where:
$\mathbf{L_0}$ = methane generation potential (m^3/tonne of MSW) and is based on the waste composition. It ranges from less than 100 m^3/tonne to 300 m^3/tonne with higher values assigned to MSW with higher organic content
R = average annual waste acceptance rate during active life (Tonne/yr)
k = methane generation rate constant. This factor depends on moisture content, pH, temperature and availability of nutrients in the waste and
c = time since SWDS closure (yr)
t = time since SWDS opened (yr)

2.4.3 LFG Collection

The first step in capturing LFG from a SWDS is to install an LFG collection system. A typical LFG collection system comprises of a collection field of wells and trenches, collection piping, a condensate drop-out and disposal system, a blower system and the flare stack. A network of collection wells, (for vertical piping system) or trenches (for horizontal piping) are installed into the waste. The basic operating principle is to apply a vacuum to extract the gases from the waste mass. The ideal objective is to apply the vacuum as rates equal to the LFG generation rate from the surrounding waste, thereby creating a neutral pressure gradient across the entire landfill surface(World Bank, 2004). For extraction of gases from already existing sites, the vertical pipes are most appropriate.

The blower system is used to generate the vacuum and supply it for subsequent use. It is usually either enclosed in a building close to the site. It consists of valves and controls, LFG flow metering and recording equipment and compressors. The condensate drop-out system removes moisture from the LFG to prevent flooding of the piping and reduce the risk of corrosion of the pipes. A flare stack is necessary as backup in case if downtimes of the utilization system (World Bank, 2004).

The costs of a collection system is a function of costs of materials- locally sources and imported, contractor availability, size of disposal site and the specific characteristics of the system design (US EPA, 1996). Considering these costs and the difficulty of the terrain in which the collection system is to be implemented experience from other projects has shown that the typically achievable collection efficiency ranges between 50-75% of total LFG generation (World Bank, 2004).

2.4.4 LFG Utilization

Typical LFG has about half the heating value of natural gas. It is also much wetter, a fact which must be considered in the design of the utilization system. Utilization systems vary in sophistication and level of pre-treatment of the LFG depending on the envisage use. LFG intended as low- and medium-grade fuel(with heating value of 16.8MJ/m^3 –) need minimal processing limited largely to condensate removal while, for a high-grade fuel uses processing will involve in addition, the separation of CO_2 and other impurities like VOCs, H_2S and other sulphur compounds from the methane as well as gas compression.

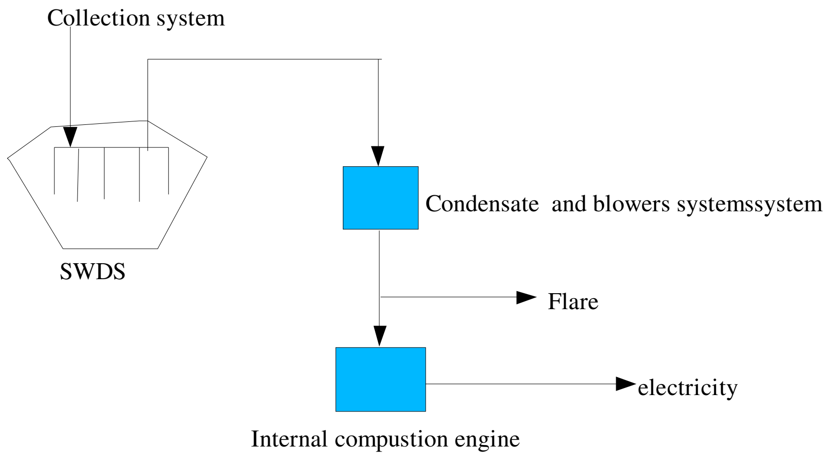

Figure 2.3 LFG to Energy Schema

Low- and medium-grade LFG can be used directly in industries for heating in furnaces, boilers and steam turbines, or can be converted to electricity using reciprocating gas engines and combined cycles engines. High grade LFG is of the same quality as pipeline natural gas and can easily be used as substitutes. It can also be used in fuel cells, and as vehicle fuels. The most popular use to which LFG is utilized is in the generation of electricity using internal combustion engines. Reseasons for this include the fact that electricity generation does not require extensive pre-processing of the fuel as even low grade LFG can be utilised. Furthermore it can much easily be integrated into existing power grids than high grade LFG can be integrated into existing pipeline networks for instance. Besides many developing countries don't have any extensive gas pipeline networks to boast of. The cost of generating electricity notwithstanding is still rather high especially when compared with subsidised electricity prices in many countries. The study focuses only on the flaring and electricity generation options for LFG. No further consideration will be given to the other uses of LFG

2.4.5 Other issues in LFGTE

A review of various studies of different LFGTE projects reveals that for an LFG capture project to be viable in terms of LFG generation, the SWDS must have the following characteristics:
- Must receive at least 200tonnes/day of waste
- Must be designed for a minimum capacity of at least 500,000 tonnes
- and Must have a minimum filing height of 10 meters. And the waste in lace should not be older than 10 years (World Bank, 2004; US EPA, 2002)

2.4.6 Energy and Emissions Market and Regulatory environment

Experience from LFGTE projects all over the world shows regulations in LFG management and the energy and emissions market are crucial for the viability of LFGTE projects. The competitiveness of

LFGTE projects depends on the market price of competing sources for energy unless there are price incentives in place. Consequently LFGTE source is most viable in countries with high energy prices. In contrast energy prices in most developing countries are too low to allow such projects be viable as experiences from south Africa and Mexico shows (World Bank, 2004).

The advent of CDM and emission trading schemes present therefore a significant opportunity for added revenues for LFTGE projects. Small wonder why of the 160 projects currently in different stages of planning and implementation as CDM projects 23% of the is from land fill or other methane capture projects. Of the 13 approved baseline and monitoring technologies, five of them (about 40%) concern methane capture from landfill. The seeming preference for landfill projects apart from the direct benefits of improved MSW management also stems out of the fact that methane, the main GHG from landfills has a global warming potential (GWP) of 21 i.e. it is 21 times as strong a GHG as CO_2.

2.5 System Dynamics and its applications in MSW\Climate change studies

A review of existing literature reveals that system dynamic models have enjoyed much use in climate change studies, Nordhaus (1992 and 1993) developed the DICE model evaluating the economic implication of GHG emissions. Fiddaman also studied energy-economy-climate interactions (Fiddaman 1995 and 2002). There are not as many system dynamics application in waste management, especially in developing countries. Sudhir et al (1997) used system dynamics to examine the interactions of informal and formal systems in the urban municipal waste management system in India. Navarro, (2003) also used system dynamics in formulating varios scenarios for solid waste management in the Philippines. There are more studies applying general systems thinking principles to waste management e.g Wäger et al, (2001) applied system thinking in building a model for MSW management in Switzerland, and Painter et al (2001) in the USA.

However, none of these studies focus particularly on emissions from waste and its relation to climate change mitigation. As at the time of writing this report there is no known application of system dynamics to the study of climate change impacts of MSW management. This is not to say there are no studies *in general* on the subject. Many developed countries have commissioned sectoral studies and published reports on the impacts of MSW management policies and practices on GHG emissions (e.g. in the EU; Smith et al, 2001 and in the USA; US EPA, 1999). Furthermore, all parties to the UNFCCC are expected to publish their GHG inventories detailing emissions from all sources including waste. The only estimation found for GHG emissions from MSW are published in these inventories and they will be presented later in section 3.3.1

3 Status of MSW management and Energy and Climate Change policy in Nigeria

Here the materials and data collected from interviews, government reports and personal observations from field visits are presented in a descriptive form.

3.1 MSW Management in Lagos, Nigeria

This section gives a brief description of MSW management in Nigeria.

3.1.1 Brief history

The Nigerian Government included in its National Policy for the Environment (1989 p.22) that solid waste must be collected and disposed of in effective and environmentally safe manners. The Lagos State Government has similar policies Bamgbose et al, 2000), but despite such policies, at federal and state levels, the waste problems still persists and is most obvious in the larger cities. Lagos clrealy is the best example of this Rapid industrialization and urbanization in Lagos combined with decades of poor governance and poor administration at all levels has contributed to the poor state of MSW management in Lagos today. In 1977 the Lagos State Waste Disposal Board (LSWDB) was formed with the mandate to collect and dispose solid waste from commercial and residential sources. The actual operations were contracted out to a foreign company, Messrs. P.D. Pollution Control of England and paid for 100% by the state government (Odunaiya, 2001). This development brought marked improvements in MSW management of Lagos state which hitherto was decentralized between the various local government areas that made up the metropolis. However, the improvements could not be sustained because the rapidly increasing population coupled with increasing corruption and administrative ineffectiveness, led to rising costs which the states budget could no longer adequately fund. P.D. Pollution Control's contract with LSWDB expired in 1985 and was not renewed, perhaps because of the change in government that year. Successive municipal leaders, in trying to impress residents, would temporarily inject funds into the LSWDB aimed at short term measures usually to reduce the littered waste and improve aesthetics, measures that couldn't be sustained because of the aforementioned reasons. In 1988, with the help of a World Bank loan, LSWDB was able to acquire equipment such as compactors, loaders, excavators and so on. The loan was also used in the construction of the Olusosun landfill. The LSWDB itself was reorganized in a bid to commercialize its operations into the Lagos State Waste Management Authority (Bamgbose et al, 2000). Not surprisingly, the performance of LAWMA was no better than its predecessor and it was later decentralized and Local councils again became responsible for collection of domestic MSW. Still the institutional arrangement was fraught with a lack of coordination between relevant units, difficulties in revenue collection.

The existing framework now is such that LAWMA is jointly managed by the sanitation units of both local government councils and State government through its Ministry of Environment. The Lagos State sanitation law of 1998 had provided legal backing to LAWMA until 2000 when a bill with the same title was passed by the state house of assembly. According to the Law, LAWMA is charged with the collection and disposal of industrial and commercial waste as well as management of landfill sites and management of transfer loading stations (Odunaiya, 2001)

3.1.2 Waste generation characteristics

According to Bamgbose et al (2000) reported the World bank contracted Lavalin Incorporated, a Canadian firm in 1999 to carry out an assessment study of waste composition and generation rates in Nigeria in 1992. The study showed that 70% of total waste generated in Lagos was from domestic sources and the rest from industry. There have also been a few other studies on waste composition in Lagos (see Table 3.2)

Table 3.1 Waste composition in Lagos from different studies (Source: Authors contruct)

<table>
<tr><th>Waste Composition</th><th>From Lavalin Inc. report (Bamgbose 2000)</th><th>From World Bank (1999) report</th><th>Cygnet 2002</th></tr>
<tr><td>Paper (%)</td><td>10</td><td rowspan="2">14</td><td>10</td></tr>
<tr><td>Textiles (%)</td><td>4</td><td>2</td></tr>
<tr><td>Plastic (%)</td><td>7</td><td></td><td>22</td></tr>
<tr><td>Non food putrescibles e.g. garden waste (%)</td><td rowspan="3">68</td><td rowspan="2">60</td><td rowspan="2">45</td></tr>
<tr><td>Wood or straw(%)</td></tr>
<tr><td>Food waste(%)</td><td></td><td>5</td></tr>
<tr><td>Others</td><td>11</td><td>19</td><td>14</td></tr>
</table>

There are widely divergent views on waste generation in Lagos. According to the World bank sponsored study is about 0.21 kg per capita per day (Bamgbose et al, 2000). This result is very likely an underestimation of the reality 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). This could easily be confirmed by the 'mountains of waste ' - illegal dumps prevalent during the period. An situation which led Rem Koolhaas, the famous Dutch architect after a six year study of the city to describe it in a 2001 presentation as a "giant rubbish dump" (Okunola, 2002). Other studies report daily waste generation rates as 0.35kg (Cygnet, 2002)

3.1.3 MSW Collection

The state introduced private sector participation (PSP) in domestic MSW collection services at the local government levels in 1997, first as a pilot program in a few states and then full fledged in all the local governments in 1999, although in public areas such as markets, LAWMA still carries out collection services. Another body, the National directorate of Employment, as part of its employment generation scheme, purchased and loaned to unemployed persons registered with it, tricycles for waste collection. They go from house to house collecting waste and are paid directly by the clients. Another set of operators in the waste sector are local waste collectors who with the aid of carts, collect waste from clients who also pay them directly.

3.1.4 MSW Disposal

Unquestionably, waste collection has been the priority, both in policy and in practice, for the state government. There is rarely any concrete plan for proper disposal. This perhaps explains the fact are no actual sanitary landfills in Lagos at the moment, or in the whole of Nigeria for that matter. LAWMA currently operates 3 dumpsites; Olusosun, Solus and Abule-Egba. Their characteristics are given in the table below

Table 3.2 Characteristics of Solid Waste Disposal Sites in Lagos (Authors construct)

Solid Waste Disposal site	**Phycical charateristics**	**Waste content**	**Life Span**
Olusosun dumpsite	42 hectares, depth: 8-15m	. Waste in place 7.7 million tonnes Total capacity. 22 million tonnes.(35% full)	Year open:1992, Year closed: 2019-2022
AbuleEgba disposal sites	depth: 12m area 10 hectares	Waste in place: 9 million tonnes(80% capacity)	year open 1983, year closed: 2009
Solus dumpsite	5 hectares, depth: 9m,	:. waste in place: 70% of capacity	year open: 1981, year closed 2008

Of the three SWDS, Olusosun seems to be the only one to meet at most of the criteria for viable LFG capture as set out in the section 2.4.5.

The bulk of MSW revenues tend to focus on collection services to the detriment of proper disposal services. But the city has grown such that the dumpsites have become nuisances and many studies have linked leachate from waste to the decreasing groundwater quality. The state ministry of environment has in the last year begun extensive rehabilitation of existing dumpsites.

3.1.5 Olusosun SWDS

This is the largest SWDS in Lagos and the only one fit to host an LFGTE project because it has a 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). According to policy, there are at least two bodies concerned with operations on the site, LAWMA and the Ministry of Environment who establishes guidelines and standards for the management and monitoring of the environment in and around the site. Scavengers live on the site in large numbers. Actual dumping started in 1992 in the southern cell at a depth of 8 meters. The cell system under which it was designed no longer exists. However this situation, at the time of writing this report is undergoing significant change. The state government has awarded the contract for rehabilitation of the dumpsite. The contract provides for the relocation of scavengers, the installation of groundwater monitoring wells, the restructuring of the waste dumping methods in order to facilitate a return to controlled dumping and compaction according to cells, construction of weigh bridges and the rehabilitation of the access road and other utilities such as lighting, water and communication. The average daily tonnage receive in Olusosun between March and June 2004 is given in the table below.

Table 3.3 Average Daily Tonnage of Refuse received at Olusosun Site between March and June 2004 (Source: authors own construct with data gathered from landfill site)

Type of waste		Monday	Tuesday	Wed.	Thurs	Friday	Sat	Sunday	**Weekly Averages**
Domestic Waste	LAWMA	730	850	890	820	815	1130	610	**835**
	Local Goverment Sanitation Agencies	150	135	150	210	100	2665	60	**835**
	Private Collectors	1340	1325	1215	1360	1220	1610	1140	**835**
Commercial waste (from markets, non harzadous 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**
Indusrial waste and metal scraps	LAWMA, NAFDAC and SON	230	250	270	225	220	250	270	**245.00**

3.2 Energy Regulations and description of energy market

The National Electric Power Authority (NEPA) established in 1972 maintains a total monopoly of generation, transmission and distribution of electric power. The industry has been faced with a lot of problems as years of neglect, corruption and mismanagement has rendered it very nearly comatose. Supply of electricity fluctuates widely and had by 1999 dropped to as low as 1500MW from an installed capacity of 5900MW (FRN, 2000). Even at the best of times, electricity supply in Nigeria before 1999 has never exceeded 2,470MW out of a total installed capacity of 5906MW (compared to over 40,000MW in South Africa during the same period[1]. Only 36% of the populace has access to grid electricity and even where a connection to the grid exists, power supply is often unreliable. Supply has always fallen well below demand especially in Lagos the commercial hub of the country where it rarely exceeded 800MW, is a paltry 15% of the estimated demand. Industries and residents have to meet their electricity needs from private generation from petrol and diesel engines (total private generation in Nigeria is about 2400MW and makes the country the largest purchaser of standby generators in the world (FRN, 2000)). These industries and private residents and pay heavily for such supply because of the ever increasing cost of diesel and petroleum arising from the deregulation of the downstream petroleum sector. Tyler G (2002) in his article in *Findings,* a World Bank journal revealed that private generation at an average cost of ^[2]19.05 is approximately two and half times the cost of publicly provided electricity. NEPA produces power from its diesel and hydro sources at over ^10.00/KWh and sells to its residential clients for between ^1.2 and ^4/KWh and to its commercial and industrial customers for ^6 - 8.5KWh (NEPA, 2004).

The new government, in a bid to boost power supply from its precariously low levels encouraged the adoption of power purchase agreements between NEPA and Independent Power Producers. Lagos state was the first to seize this opportunity as it immediately entered into negotiations with Enron (who later

[1]From the website of the South African National Electricity Regulator (NER)
[2] 1^ - Nigerian Naira (1US$ = ^100 .Approx.)

sold the plant to AES Energy) for the supply of 270MW of electricity from barge mounted diesel engines to the state. This was a great cost to the state who had to shoulder the difference between the price - ^8.50 per KWh - AES offered to sell and the price - ^3.80 per KWh - NEPA was willing to pay (NBI, 2004). There have since been a few other such power purchase agreements in the other regions of the country all with separately negotiated prices non of which, according to personal communication with NEPA officials, has never exceeded ^5/KWh. The Federal government also embarked on extensive revamping of its own generating facilities such that electricity production by the end of 2001 electricity supply had nearly reached the 4000MW target it set for itself[1].

The government realizes that it cannot by itself fund the adequate provision of energy services and directs its reforms towards attracting private sector participation in the sector. Towards this end, the Federal Government through its Electric Power Sector Reform Implementation Committee sent a bill to the National Assembly which recommended the "functional segmentation" of NEPA into a number of competing, privatized generation companies, a number of privatized distribution companies, and an independent transmission company all to be regulated by an independent regulatory body(FRN 2000).

The government also realizes that it must review its tariffs upwards and according to the proposed bill (which has been passed by the National assembly but still awaits presidential assent before it becomes law) the government tariffs would be set by the independent regulatory body with a view to enabling full cost recovery and allow investors make reasonable return on investments (FRN 2000). The interests of low income electricity consumers would be protected with the introduction of a uniform "lifeline tariff".

The government has targeted natural gas as the fuel of choice for electricity supply in the future and its estimated marginal cost over the next 20 years is estimated to be about US$39/MWh(NEPA, 2004). It has also signed an agreement with Eskom of South Africa towards the construction of a coal fired 2000MW plant to make use of its significant and hitherto largely unutilized coal reserves.

There is no national renewable energy policy in the country. The only mention of renewable energy in the proposed Power Sector Reform Bill was in reference to its adoption as off-grid supply to rural areas especially solar power.

3.3 Development of Climate Policy in Nigeria

Nigeria only very recently ratified the Kyoto protocol on the 30th of September 2004. The delay in ratifying the protocol stems from the countries membership of OPEC[2]. The quote below depicts OPECs view of the protocol from the organisation's,

"We are still not satisfied that our legitimate concerns about the adverse impact of response measures on our hydrocarbon-dependent economies have been properly addressed, in spite of the provisions made for this in both the Framework Convention and the Kyoto Protocol" excerpts of speech by OPEC secretary-general Dr Alvaro Silva-Calderón at the ninth COP in Milan, 2003 *(*OPEC 2003*)*

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[1] Obtained from the website of the Federal Government of Nigeria
[2] Organization of Petroleum Exporting Countries

OPEC members are concerned that the reduction in energy demand that will accompany the implementation of the protocol will slow growth in their revenues from oil (Barnett et al, 2004). The country's ratification of the Protocol may not be unconnected to the realisation of the inevitability of the Kyoto's Coming into force, coupled with the fact that the country has more to loose from impacts of climate change than it would lose from loss of revenues as a result of lower energy demands(Barnett et al, 2004).

The Federal Environmental Protection Agency (FEPA) (now the Ministry of Environment since 1990) has been the body responsible for climate change issues in Nigeria. Negotiators for the COP[1] where usually drawn from FEPA as well as the Nigerian National Petroleum company (NNPC) - the state owned oil company as well as the foreign ministry. Later Inter-ministerial Committee on Climate change was set up to foster communication across relevant ministries and to provide cross-sectoral advice to government on implications of climate change policies. This committee consisted of representatives from

- Federal Ministry of Agriculture
- Federal Ministry of Water Resources
- Federal Ministry of Finance
- Federal Ministry of Industry
- Federal Ministry of Justice
- Ministry of Petroleum Resources
- Ministry of Foreign affairs
- Nigerian Meteorological Agency
- National Planning Commission
- Energy commission of Nigeria
- National Electric Power Authority

Sometime later another committee was set up called the National Committee on Climate Change (NCCC) whose members where in addition to those above drawn from the NGOs, the Private sector and academia. The NCCC's major objective was to coordinate activities concerning the preparation of National Communications to the UNFCCC which was finally submitted to the UNFCCC in 2003.

3.3.1 Past GHG inventories of Waste sector

Before that there has been a number of other GHG inventory studies. In 1989 the European Economic committee under the African and the Caribbean's Project (APC) III provided funding for the study of GHG's and other toxic air pollutants in Nigeria for the year 1988. The study covered CO_2 CH_4, N2O, CO, NOx, VOC, SO2, PM and Pb. Emission from solid waste were based on waste generation estimates obtained from the respective regional waste management boards and was estimated to total 182,000 tonnes CH_4 in 1988. Emission factors where adapted from IPCC default values and from available literature.

[1] Conference of Parties

Next came the US country Studies Program in 1993 which provided funding for the study of emission inventories for CH_4 CO_2, N_2O, CO, NOx and NMVOC in 1990 and the economic implication of their mitigation. The emissions estimates from MSW are, a daily per capita waste generation rate of 0.49kg, an urban population fraction of 17%, MSW managed by landfills, open burning in unmanaged sites, and no open burning in unmanaged sites respectively taken as 5%, 25% and 70%. Based on these assumptions, CH_4 emissions from waste was estimated at million tonnes in 1990.

The Global Environmental fund through UNDP also gave funds towards the preparation of an Initial National communication to the UNFCCC as stipulated in Article 12 of the convention. The study was published in November 2003 was based on emissions in the year 1994. CH_4 emissions from waste for that year were estimated to be million tonnes.

Other estimates for CH_4 emissions from waste are given by the following table

Table 3.5 CH_4 emissions from MSW from past GHG inventory studies

Year	1988	1990	1994
Study	EEC-Project Environmental Monitoring and Impact Assessment(1992	US Country Study Project in Nigeria: Least Cost Reduction Strategies and Macro-Economic Impacts (1997)	Initial National Comunication to the UNFCCC (2003)
Results (million tonnes CH_4)	0.182	64.51	213

The results of the Initial National communication of 213Gg methane in 1994 implies that MSW accounted for 4% of total emissions methane emissions and 11% of methane emission from the waste sector, with industrial and domestic waste water accounting for the remaining 89%. Interestingly, this is at variance with the general trends in other developing countries. In India for instance according to their own Initial National Communication to the UNFCCC, MSW accounts for 53% of total methane emissions from the waste sector and in Malaysia and the Philippines, it accounts for 82% and 57% respectively.

4 Results

This chapter presents the results of the analysis of data collected from the visits to the field. The main thrust 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 presented, 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 where made. The model takes a modular design as shown in figure 4.1 (see appendix for full structure of model).

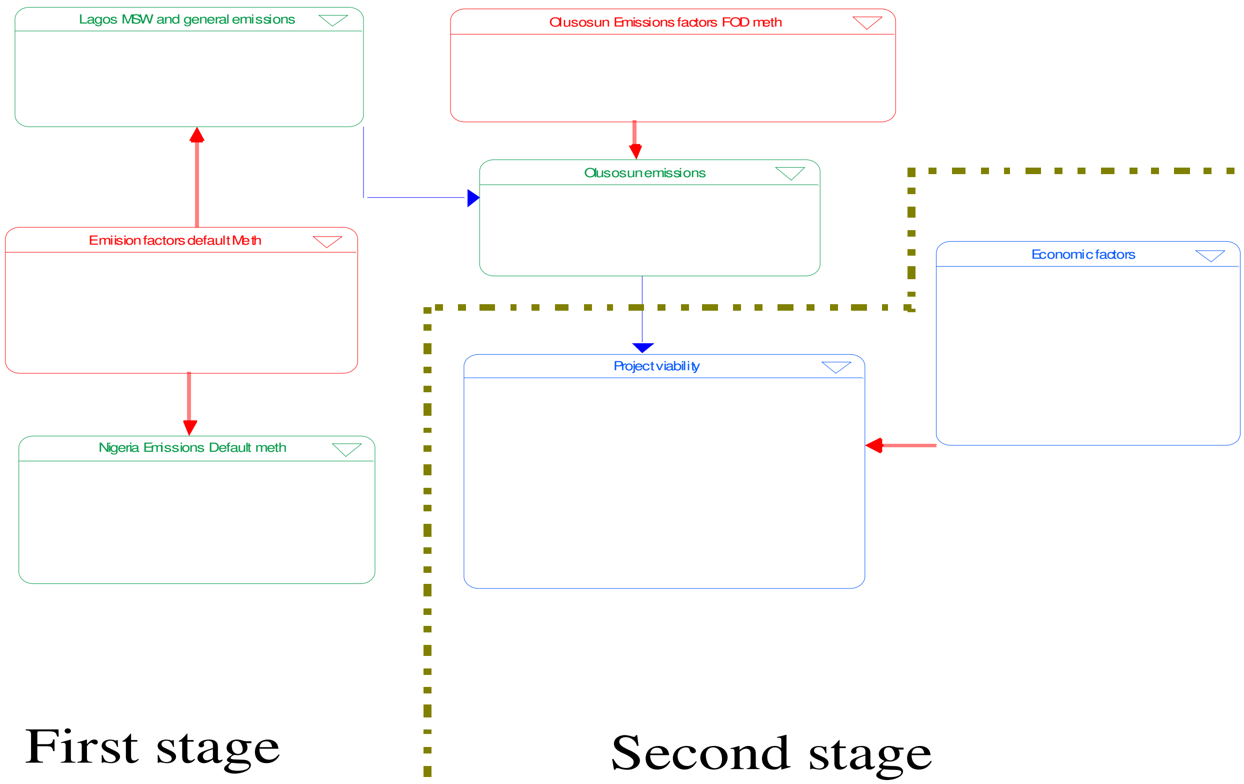

Figure 4.1 Overall general structure of STELLA model

4.1 Assessment of Resource Potential

The availability of methane resource in sufficient quantities is essential to the project's success. The specific factors affection its production from MSW in Nigeria and in Lagos is particular therefore, are described below.

4.1.1 Factors affecting CH_4 emissions

As mentioned elsewhere, 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 there 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 4.2 below captures the interactions that affect CH_4 emissions from MSW in Lagos.

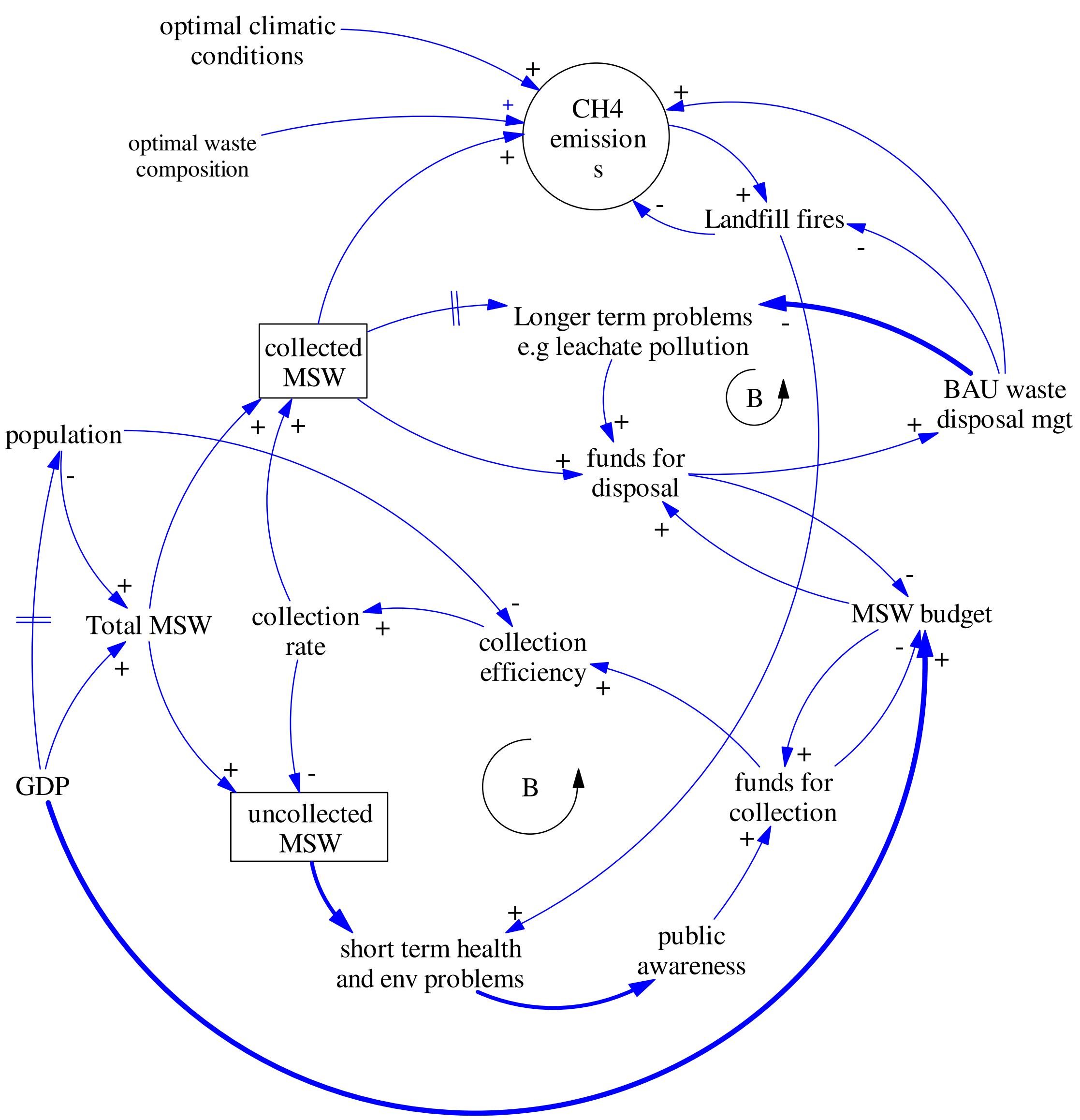

Figure 4.2 CLD showing factors affecting CH4 emission from MSW disposal sites

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, as explained in the last chapter, 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 above) 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.

With the recent change to democratic office in 1999, the quality of public administration, has began to improve somewhat (World Bank, 2004b), and government is more responsive to the needs of its electorate, within limits of its financial capabilities naturally. There has since been a decidedly improved collection system (described in chapter 3) which has seen a sustained increase in collection rates. There has also been increased attention to proper disposal systems in response to the environmental problems arising form bad disposal systems such as leachate pollution, odor, and smoke from landfill fires caused by the methane emissions mixing with oxygen. The increased spending has led to marked efforts in the improvement of the state of current disposal sites. All three disposal sites in the state are undergoing major renovation (see pictures in Appendix), such as repartitioning of dumpsites into cells, groundwater monitoring and some degree of leachate management. There are also plans for daily sand cover of waste to reduce the occurrence of fires and the prevalence of disease vectors.

However, such improvements, as they are currently being planned and implemented, conspicuously exclude the capture of landfill gas. A situation which will inadvertently favors CH_4 emissions as depicted in the CLD. Improvements in landfill operations such as waste compaction, prevention of landfill fires and so on creates better anaerobic conditions for natural biomethanation. Also improvements in collection efficiency will ensure a constant flow of waste resource.

4.1.2 Emission module parameters

The CLD in the last section formed the framework for the design of emission calculation modules in STELLA. A simplified picture of the module structure is shown in Figure 4.3. The figure shows methane emissions as being influenced principally by two main factors: amount of annual MSW inflow into landfills and a composite variable termed 'emission factor'. The later encapsulates all the factors which directly affect methane emissions from waste deposited in SDWS depicted in the CLD above (figure 4.2). The

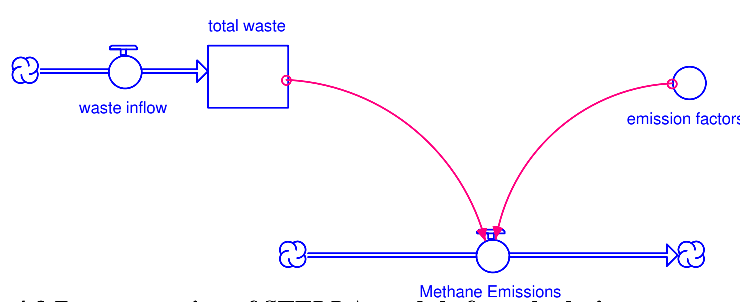

Figure 4.3 Representation of STELLA module for calculating CH4 emissions (Own construct)

variables that make up the 'emissions factors' vary slightly depending on the methodology used as will be seen in the following sections.

4.1.3 Results of module for estimating methane emissions

The module calculating national and Lagos emissions was based under the following assumptions

- National daily 'per capita MSW generation' was estimated to increase from 0.26kg to 0.36kg. For Lagos, it is assumed to range between 0.35kg to 0.6kg. This difference is based on the assumption that Living standards in Lagos, being the nations economic centre can be assumed to be higher than the national average.
- urban national population= 46%
- 'urban population of Lagos' = 85% of total population (Okunola, 2002)
  Future population = present population x (1+growth rate) $^{\text{no of years}}$
  Population growth rates for Lagos ranged from 9% in the early seventies to currently somewhere between 5-8% and is projected to further reduce to between 3 and 3.6 % by 2015 (UN 1999; Okunola, 2002)
- MSW 'collection efficiency' in Lagos varies from 60% in 1991 to 80% in 2005 and to 90% from 2015 onwards. For Nigeria it is assumed to vary from 50 to 80%
- MCF (Methane Correction Factor): is a function of the quality of the management of disposal sites in Lagos. Following the explanation of trends in waste disposal in Lagos in the last section, the figure ranges from 0.4 in 1991 when SDWS where almost unmanaged to 0.8 in 2005 where significant improvements in SWDS management have been put in place to 0.9 in 2015 and onwards.
- DOC (Content of degradable organic carbon was calculated based on figures in table 3.2 to range from 0.14 to 0.18. This is consistent with the values adopted in countries with similar socio-economic status (Bingemer and Crutzen 1987)
- DOC_F is the fraction of DOC above that is dissimilated. As mentioned in the chapter 2, it depends on the temperature in the landfill which according to Cygnet (2002) is about 35^{o}C. This translates to a $DOC_F = 0.77$
- OX (oxidation factor) The default value as recommended by IPCC is 0

4.1.3.1 Methane emission projections for Nigeria

Applying these assumptions[1] in the model gives the results presented in the charts below (Fig 4.4). The results suggests emission from waste in Nigeria was below 100GgCH_4 in 1994 but grew to reach up to 231 Gg CH_4 in 2004 in contrast with the 213Gg in 1994 as reported by in the country's initial national communication to the UNFCCC (FME, 2003). If the results of the other calculations in the national communication are to be believed[2], results of these estimates implies that the MSW disposal sector

[1]Emission factors as assumed to be the same for Lagos and at national levels except otherwise stated

[2]A review of the Nigerian Government's initial national communication revealed some inconsistencies between the results and some of the assumptions on which they are based. For instance MSW emission estimates are inexplicably higher than what the assumption on which they are based suggests. In addition some of the assumptions are clearly out of place, such as one that estimates the national urban population fraction of 17.5%. A more realistic estimate would be the UN's (46% as at 2000 and rapidly growing). Another unrealistic assumption is percentage of DOC. The national communication assumes a

accounts for about 0.45% of total methane emissions in 1994 compared with 25% in Egypt and 6% in Indonesia(UNFCCC 2004). Most significant methane sources pointed out in the national communication are from agriculture (39%), wastewater treatment (32%) and energy (25%).

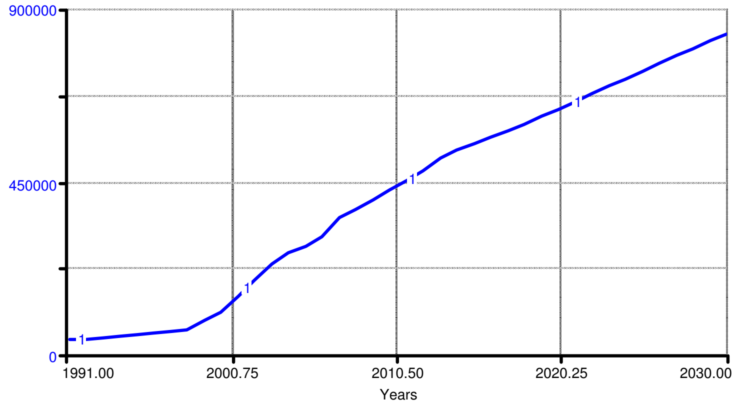

Figure 4. 4CH4 emission trends in Nigeria (tonnes) (Source: own construct)

Figure 4.3a shows emissions in the National emissions trends. The chart confirms the explanation above that limited improvements in collection efficiencies and SWDS management started by the current administration will significantly increase emissions. Average annual increase in emission before 1999 averaged only 8-10% but jumped to 25-30% after 1999.

4.1.3.2 Methane emission projections for Lagos

Emissions from Lagos are given in the chart in figure 4.5 and show the same trends as the national level as expected since they were basically derived under the same assumptions.

According to the analysis, methane emissions for Lagos range from 8.4Gg (10.5 million m^3) in 1991 to 80Gg (100.7 million m^3) in 2004. Again as before we see the marked increase in 1999 that is as a result of improvements in MSW collection efficiency and landfill operations that started during the period.

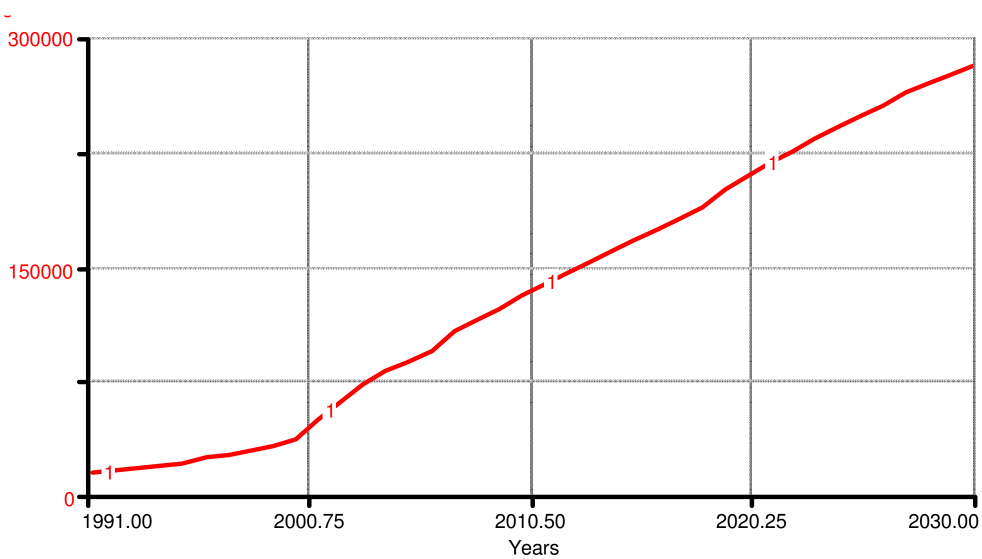

Figure 4. 5CH4 emission trends in Lagos (tonnes) (Source: own construct)

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figure of 0.40, much higher than the 0.14 to .018 range suggested by Bingemer and Crutzen (1987) whose study formed the basis of IPCC guidelines.

4.1.3.3 Methane emissions from Olusosun SWDS

Narrowing down to Olusosun SWDS where even more data is available, and where the emission model used (the first order decay (FOD)model) is a better representation of the fate of CH_4 emissions in landfills, the results are as shown in the charts below under the following assumptions.

- L_o – Methane generation potential (same as MCF*DOC*DOCF*16/12 in the default method) and here assumed to be about 150m^3/Mg. A conservative estimate when compared with 1(0m^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

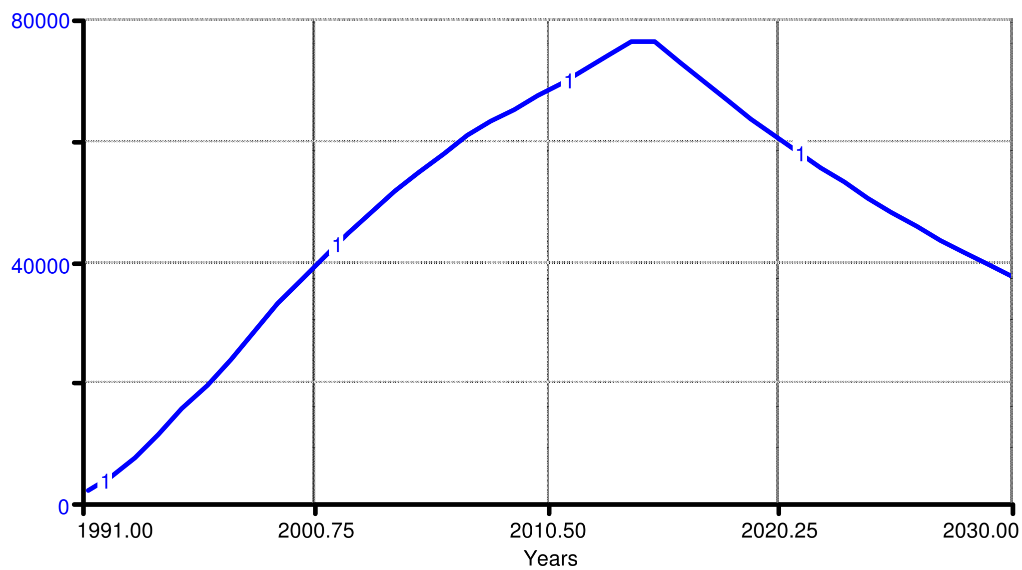

Figure 4.6 Methane emissions from Olusosun SWDS (Source: own construct)

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 L_o by ±15% shows that this varies from a low of 47,000 tonnes to a high of 78,000 tonnes CH_4.

4.1.3.4 Utilization potential

Although there are various uses of methane generated from landfills, this study will only consider flaring and electricity generation. Allowing for a 25% uncertainty in the following figures and supposing the efficiency of the collection system in place is 60%, the potential electricity generation from Olusosun is depicted in the chart below(figure 4.4) under the following other assumptions.

- An energy generation potential of 33.8MJ/m^3 of methane,
- electricity conversion efficiency of internal combustion engine is 25% with an availability factor of 85% (i.e. 15% downtime)

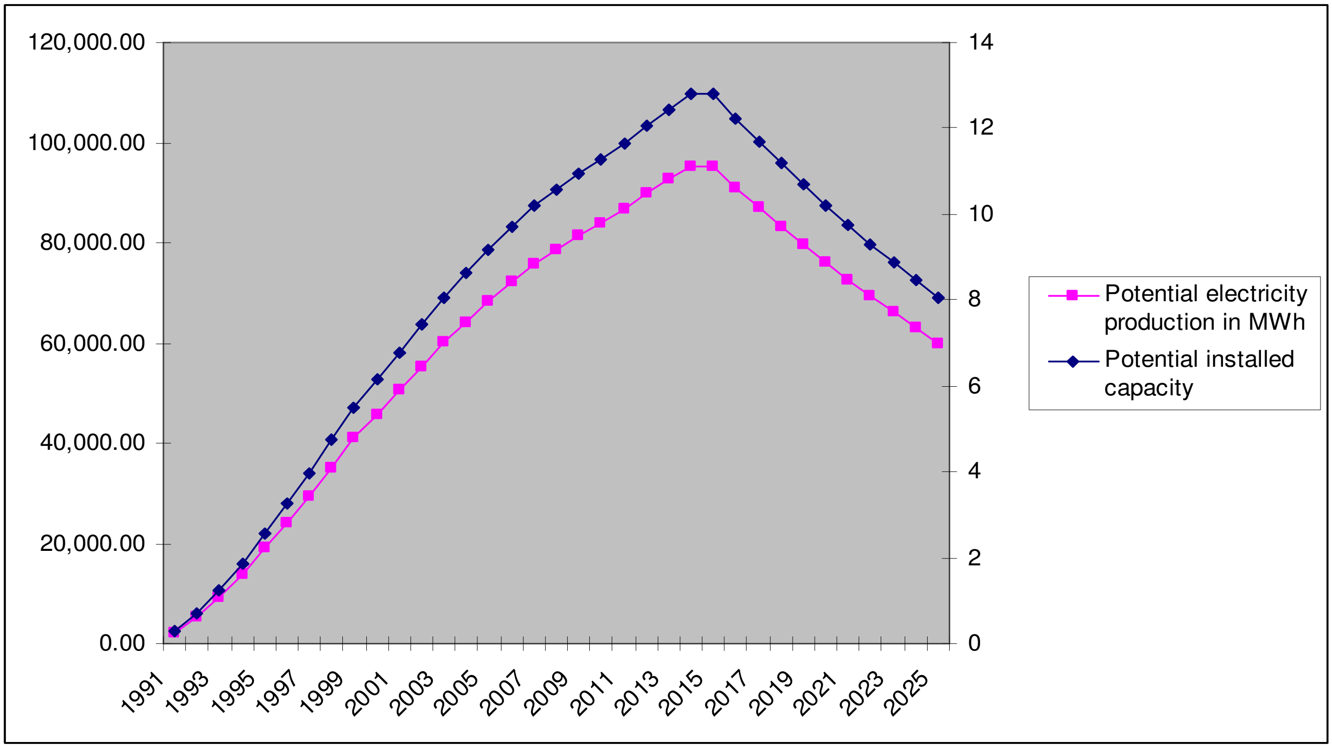

Figure 4.7 Potential electricity generation from Olusosun SWDS

From the graph we see that should the plant start operating in 2005, it is possible to produce about 70,000MWh from say, an internal combustion engine with installed capacity of about 8MW, and to do until 2005.The extra gas is flared.

CERs are generated whether the methane is flared or combusted as in both cases methane is destroyed to form the less potent CO_2 and water. According to the model, the landfill could generate about 544,000 tCO_2e annually or up 13.124 million tCO_2e of methane emissions over 21 years. According to CDM regulations, CER's are also generated from the CO_2 avoided through the displacement of grid based electricity

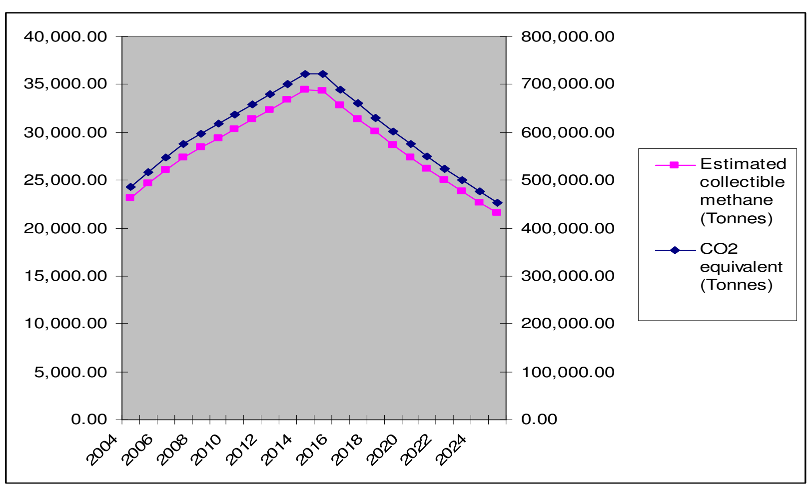

Figure 4.8 Potential ER's from Olusosun

by electricity produced from the project (UNFCCC 2004b). Such emissions are not considered in this study.

4.2 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 as. For instance CDM regulations require that parties must have ratified the Kyoto protocol and set up DNAs in order to take part in its emissions market. Some of these issues as they affect the viability of the proposed LFGTE projects and their interactions are represented in the CLD below.

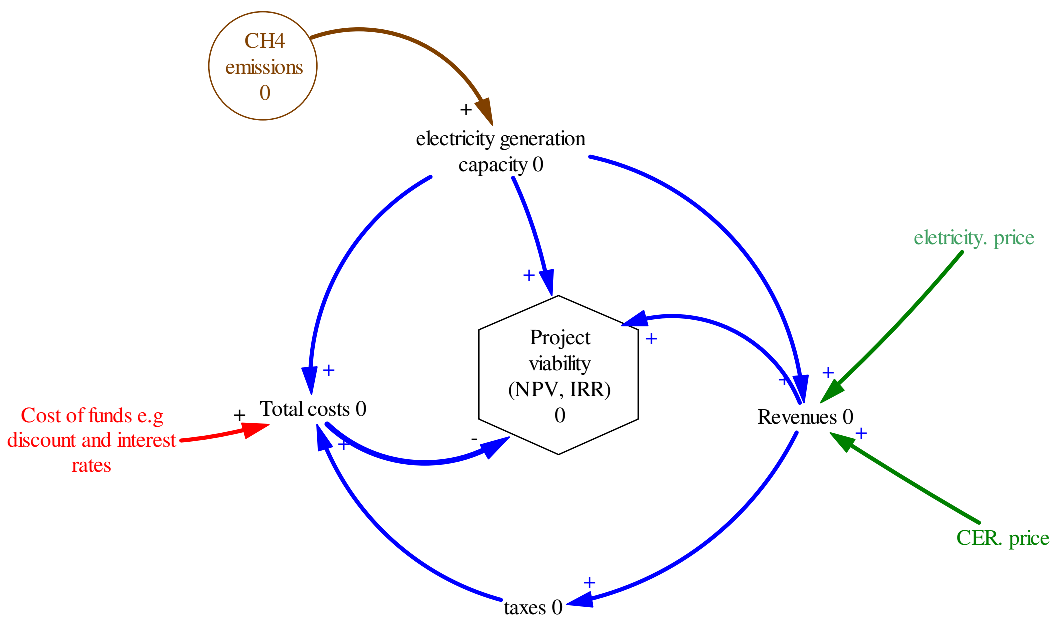

Figure 4.9 CLD of financial viability of project

Economic viability as measured by NPV and IRR[1] is a direct consequence of the costs associated with the project and revenues accruing to it; all other factors that affect the projects viability could be said to e.g electricity price, CER price, interest rates and viability feed in through these two components.

[1] NPV –Net present Value and IRR – Internal Rate of Return. NPV is the discounted net income of the project over time and represents the financial value of created by the project. IRR is the discount rate when NPV = 0 and usually depicts the lowest discount rate at which the project will be viable (Barish, 1962)

4.2.1 Projects costs

Costs 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 (US EPA 1996). The costs as applied in this study are given in the table below. Based on these costs, estimates of the projects costs range between US$50 MWh to US$110 (as determined by a sensitivity analysis varying the costs by ±25%.

Table 4.1 Summary of LFGTE system costs (Source: Adopted from US EPA, 1996)

Activity	Capital costs(2004 US$)	Operating and Maintenance costs (2004 US$)
Planning design and engineering	1,600,000.00	-
Collection system (including transmission)	4,500,000.00	271,000.00
IC engine	12,200,000.00	3,000,000.00
Flare system	254,000.00	28,000.00
Total costs	**18,554,000.00**	**3,299,000.00**

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 projects would qualify as a very large CDM project (UNFCCC 2004a) and according to Krey (2004) the transaction costs associated with registering and validating emissions from the project under the CDM would be about US$0.123/ tCO_2e.

4.2.2 Revenue Streams

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$/$tCO_2e$ (Haites, 2004)

4.2.3 Results of financial analysis

To aid policy guidance, cash flow analysis of the viability of the project under these factors as shown in the CLD above is done in three scenarios:
1.) Funding from local sources at current discount rates
2.) Funding from foreign sources such as the World banks carbon fund
3.) Flaring only option (no electricity generated)
The major distinguishing factor between the first two scenarios is the cost of capita for the project as determined by interest and discount rates. According to Barish(1962) high interest rates is one major impediments to projects finance for projects in developing countries.

Under these scenarios NPV and IRR are calculated under the following remaining assumptions

- Project lifetime of 20 years as consistent with projects of this nature (US EPA, 1999)
- Tax rate on all profits of 30%[1]
- The analysis includes capital costs in the year they are incurred and as such it is not necessary to include depreciation (Barish, 1962)
- Assuming all other costs are as given in section 4.2.1

4.2.3.1 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 currently 18% (CBN 2004). Interest rates on borrowing from banks are typically in the 20 – 25% range (NIPC, 2004). 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 4.2 NPV (in US$) under different CER and electricity price ranges (Source: Authors Construct)

		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 above are based on different assumptions under which electricity price for the project could be negotiated. US$21 is the lowest price for which NEPA sells to its customers, US$50 is the highest NEPA buys from IPP and US$65 is the price municipalities pay for electicity for street lighting (all per MWh). Personal communication with NEPA officials revealed it is unlikely for NEPA to buy at higher price that US$50/MWh given its recent attempts at commercialization. Even assuming that price could be negotiated, 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% 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 interests rates .

[1] The prevalent corporate tax rate in Nigeria (NIPC, 2004)

The option of public funding, which otherwise would have been cheaper source of fund can practically be ruled out except there are sudden changes in the perceptions of the officials in LAWMA. None of the officials interviewed indicated interest in capturing LFG in the medium to short term. Not even the state's medium to long term policy as contained in its SEEDS strategy contained any reference to LFG capture (LSG SEEDS, 2004).

4.2.3.2 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[1] that the project is funded at 8% interest rates yield the following

Table 4.3 NPV (in US$) under different CER and electricity price ranges with 8% inetrest rates (Source: Authors Construct)

		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.

4.2.3.3 Scenario 3 Flaring Only

Further analysis of the scenarios above point to the fact that CER 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. Feeding this into the i.e reduced project capital costs of US$6,354,000 and maintenance costs of US$299,000 yields IRR of about 27%. This implies the project has much higher returns if flaring without electricity is planned even when the source of funding is local funding.

[1] In reality funding arrangements are much more complicated. To surmount the problem of funding for the The Nova Gerrar landfill project in Brazil, the sponsors British supplier of flaring and energy systems agreed to lease their equipment to the sponsor using income from sales of ER's (which the corld bank had committed itself to buying.) In other cases funders agree to advance part or all upfront payments for project construction under varios debt and equity arrangements (Kossoy 2004 ; Bishop 2004)

4.2.3.4 Impact of social factors

Larger socio economic trends such as corruption, level of infrastructure and so on also have implications for the economic viability of any project (Barish, 1962). Some of this factors as they are thought to affect the project are shown in the CLD below

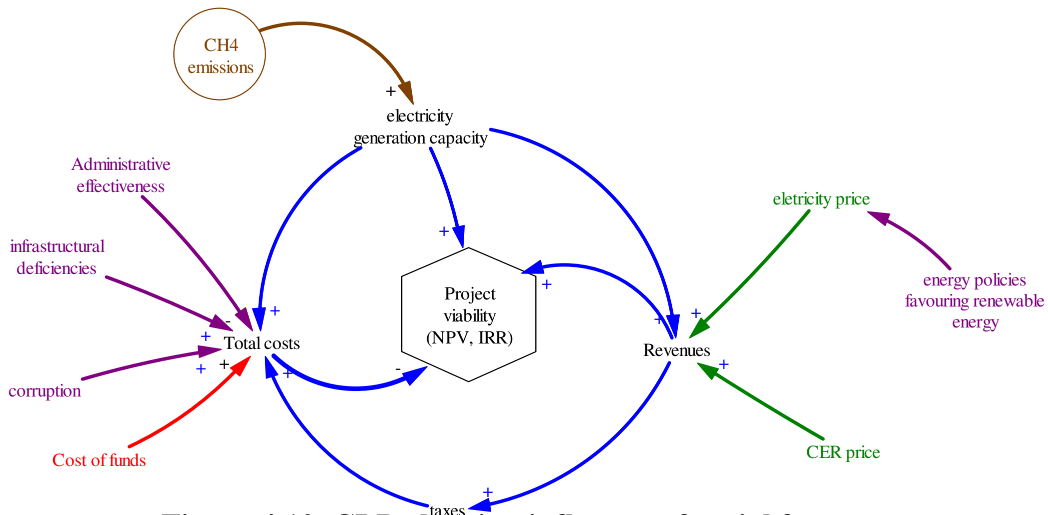

Figure 4.10. CLD showing influence of social factors

The CLD shows that these socio-economic factors impact on the projects viability by influencing the projects costs and revenues. One such influence path is Lee et al#s (1989, 1992) study on the costs of infrastructural deficiencies for manufacturers in Nigeria comparing them to similar costs from Indonesia and Thailand (1996). They opined that private entities such as companies and individuals often are obligated to spend on infrastructure like telecommunication, transport, water supply, electricity and so on to the extent which the public infrastructure is deficient invariably increasing their cost of doing business. They estimate for instance that while firms spend anywhere between 5 to 9 times the normal costs on private water and electricity provision for these services. They concluded that such costs are lower where the quality of public provision of these services is higher. A related but separate study corroborates this, estimating that that it cost firms 15% more to produce soap in Nigeria than in India solely because of the difference in infrastructure provision (Tyler, 2002).

The impacts of corruption, especially on the transaction costs, while clearly perceptible are rather very difficult to measure. There the considerable body of literature confirming the economic costs of corruption on development in general but they focus mostly only on the over effects, actual empirical analysis of the costs impacts of corruption that could be relevant to this study could not be found. An exception is the estimate by Wade.(1982) that corruption in Asian countries increased costs of acquiring goods and services by 20-100%.

Corruption, state of infrastructure and so on not only directly increases the projects costs as shown in the CLD, but also and equally importantly, reduces the country's credibility, there by affecting FDI and other funding inflows as has been the case in Nigeria[1]. This thereby will increase the discount rates investors will require for investing in such a country thereby increasing the costs of funds.

Say for the sake of analysis the projects costs are raised by 15% and 20% attributed to infrastructural deficiencies/administrative ineffectiveness and corruption respectively, the model results show that the IRR for the project in the second scenario drops from 18% to 14.5% implying the project might have a harder time being viable. Adopting the upper limits of Wade’s estimate of the impact on corruption on project costs, the model run shows IRR drops to 9%. Implying the project is barely viable under this condition.

4.2.3.5 Projects benefits and impacts

The likely impacts of this project, apart from its contribution to climate change mitigation would typically include the following

- Gas extraction prolongs the life of a landfill(US EPA, 1996), thereby saving the municipality some costs of building new landfills
- Scavengers could possibly be trained to work under more hygienic circumstances than the currently operate
- The project will create jobs, as well as serve as a skill development and capacity building tool for training of government officials.
- Should the project be successfully implemented, it will increase awareness of the public in climate change mitigation issues and opportunities such as CDM an other emission trading mechanisms.

[1] Nigeria has about the lowest overseas development assistance ODA per capita in Africa and one of the lowest in the developing world, FDI has also in the past steadily decreased during the military regimes although the change is now been reversed with the inception of the new democratic government (World Bank, 2004b)

5 Conclusions and Recommendations

To a large extent, although the situation as described in this study mostly focuses on Lagos, it could be argued that it in typifies the conditions of the whole country. Nigeria is an oil producing country with no real climate policies (its efforts to reduce flaring of natural gas stems not from climate concerns but from economic gains it stand to benefit). Climate change is apparently not seen as a national priority in the face of more pressing needs for economic growth. This situation, to a lesser degree in some cases, describes the position of many developing countries (Ryner and Malone, 2001).

It is hardly surprising therefore that the country's approach at MSW has been short term and directed at addressing only the most directly perceptible impacts of waste disposal, especially as its affects public health. Climate concerns are not even considered at all. Capturing LFG from SWDS is a costly procedure as results have shown which municipalities may well not be able to afford on their own, especially considering their scarce resources in the face of more pressing problems of poverty. Even if they could, chances are they have no desire to do so, for two reasons. First is the fact mentioned earlier about climate change mitigation not been a priority, second is the fact that energy prices in Nigeria are currently low, especially considering that natural gas, which is increasingly forming the major part of the fuel mix, is supplied at heavily subsidized prices. The result of the study also has shown that the cost of the local private funding is too high to allow the reasonable rate of return for the 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 cannot 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).

In conclusion it is interesting to note that although this study started out on the hypothesis that electricity from LFG will be viable under climate change mitigation strategies, the result shows otherwise. Recommendations arising from this conclusion would be that the project would be best carried out by investors with the projects finance coming from foreign course. The conclusions also suggest that the project at least in the beginning should be panned to only receive revenues from CER's generated by methane destruction by flaring only. It must however be noted that these conclusions arise only from the assumptions made in the course of the analysis. Because of the lack of data, the level of uncertainties and approximations at every stage of analysis in the study such that it cannot (and was not intended to) form the basis for a business decision to invest in LFGTE in Nigeria.

Lastly, the results of this study are limited in that it does not consider the life cycle of the waste in calculating emissions. It does not also consider the impacts of policies like waste recycling and reuse on the waste stream and this can be the subject of future research. Another drawback of the study is the fact that considers only limited options for LFG utilization. Not only in terms of technology for instance, is LFG channeled to private industries in some countries as private electricity generation. It would be instructive to examine which industries in the vicinity of the site could find use for energy or electricity from the LFG produced.

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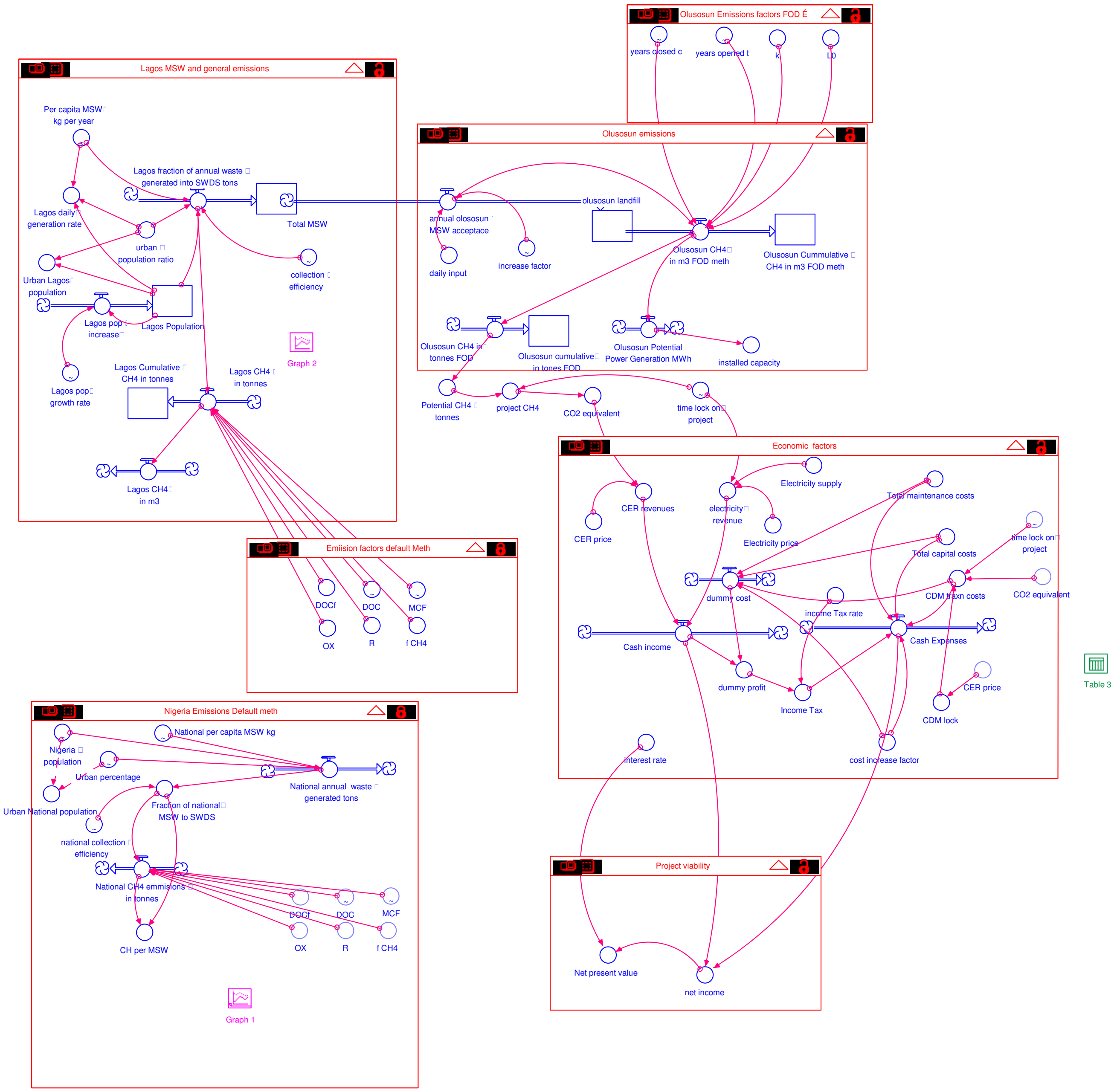
7 Appendix



Appendix 1: Structure of STELLA Model