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SUSTAINABLE URBAN WASTE MANAGEMENT: ANALYSIS OF UNTAPPED BIO-ENERGY RESOURCES OF LAGOS METROPOLIS

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ABSTRACT

The purpose of this paper is to make a review of renewable energy generation and recovery from untapped bio-energy resources within the present Lagos metropolis.The efficient use of bio-energy has been tagged as part of the solution to be adopted for emission reduction, and as a necessary inclusive tool towards creating a sustainable city. Most cities in Nigeria are faced with a waste management problem. The insufficiency of services results in deterioration of the urban environment. The focus of this thesis is on creating a sustainable Lagos city by utilizing the opportunities that come with the utilization of untapped biomass resources.

In order to fulfill this purpose, the present waste management methods were analysed, data was collected in the form of books, articles, journals, online sources and some interview were carried out. In the last few years, a lot of laudable actions have been achieved in Lagos waste management, but with the annual increasing population, the challenges seem growing in bounds.

The research was carried out within the scope of the CONNECT project. The study lays emphasis on potentials of efficient municipal solid waste management, sawdust utilization and proper engineering and management of landfill sites. A well planned integrated waste management, which includes efficient solid waste, landfill gas and sawdust utilization, will take Lagos city to the path of sustainability.

Keywords:

municipal solid waste, renewable energy, landfill gas, biomass, urban cities

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CONTENTS

1 INTRODUCTION 1

2 BRIEF HISTORY OF ENERGY SOURCES IN NIGERIA AND LAGOS 3

2.1 Energy Sources in Nigeria 3

2.1.1 Biomass resources in Nigeria 5

2.1.2 Exploring biomass in Lagos 6

2.2 Lagos within the global view 7

3 LAGOS: GEOGRAPHY, DEMOGRAPHICS, AND ECONOMICS 8

3.1 Lagos and its unique attributes 8

3.1.1 Lagos population and urban structure 9

3.2 Past and present practice of waste management in Lagos 10

3.3 Brief Comparison of Lagos Waste Management Authority (LAWMA) with Päijät Häme Waste Disposal Limited 12

3.4 Brief comparison of Lagos waste management with Accra waste management 16

4 BUSINESS POTENTIALS: UTILIZING LAGOS MSW, LANDFILLS AND SAW DUST 19

4.1 Lagos municipal solid waste 19

4.1.1 Estimated energy generation potential of Lagos MSW 22

4.1.2 Challenges of waste management in Lagos 24

4.2 Unused sawdust at Okobaba sawmill 28

4.2.1 Briquette production 29

4.2.2 Bio coal technology 31

4.3 Recovery potentials from Lagos landfills : Olushosun landfill as a case study 32

4.3.1 Categories of Lagos landfills 32

4.3.2 Physical characteristics of Olushosun landfill 33

4.4 Energy stakeholders in Nigeria 36

4.4.1 The Energy Commission of Nigeria 36

4.4.2 Federal ministry of environment 36

4.4.3 The Lagos state Government roles 37

4.5 CONNECT project model: A necessary intermediary 40

4.6 Doranova model for Zambia 41

4.6.1 Doranova's perspective on Lagos 43

5 RESULTS 44

5.1 Estimation methods for calculating methane emission from landfills 45

6 CONCLUSION 52

SOURCES 53

APPENDICES 60

1 INTRODUCTION

The cities of the third world countries are growing at a very alarming rate compared to those of the western world. UN-Habitat report observed that Africa is the fastest urbanizing continent, having cities like Cairo, Lagos and Nairobi growing at rates that would make them triple their current sizes by the year 2050 (UN-Habitat 2010). Such high rate of city growth has implications for municipal waste management among other social services required in the urban communities. Efficient waste management is a necessary ingredient towards creating a livable and sustainable environment. Sustainable waste management is a process that must begin with effective waste collection. It should not be left in the hands of illitrate and miscreants in order to save the city from the problem of poor planning, diseases and hazardous gas emission. The management of the materials, their separation and recycling could be bring a substantial revenue and enhance the transition of the state towards its metamorphosis into a mega city.

There have been efforts to meet the increasing global energy demand due to rapidly changing lifestyles and human activities. Relying on the traditional fossil fuel alone is like taking a risk of backward trend in modern developmental strategies (Mohammed, Mustafa, , Bashir,, Mokhtar, 2012, p 257-268). As fossil fuel reserves are limited and declining by the day, and considering the negative consequences of its carbon emission to the environment, these make renewable energy a worthy venture that has attracted global interest towards energy solution.

Production of renewable energy from biomass is one of the main alternative energy resources because of its global availability. About 10% of global energy supply is generated from biomass while the remaining 90% are obtained from fossil fuel and other conventional energy resources. Observing this trend closely clearly indicates that the entire world is exposed to serious environmental hazard if the trend is left unchecked. (Hamzeh, Ashori, Mirzaei, Abdulkhani, & Molaei 2011 , p 10.). Due to the growing world population, increasing energy demand per capita and global environmental concern, there is a need for long-term alternative energy supply. The world's energy demand is expected to grow by about 50% by 2025, especially in the rapidly emerging countries. (Agbro & Ogie 2012, P 149-155).

The aim of this study is to explore three sources of bio energy within Lagos Metropolis, by studying the operations of waste management in Lagos city, to review the prospects of utilizing the potentials of Olushosun landfill, and saw dusts that are generated daily at Oko baba wood processing factories.

The research method adopted for this study involved a literature review of both online and offline academic materials. Materials used include books, reports and scientific publications. Interviews were also conducted with related industry experts.

For the purpose of this study, municipal solid waste (MSW) will be defined as the common urban waste, which includes predominantly household waste, but wastes from sources like commerce, offices and public institutions are included. It also include any other material resulting from operations of residential, municipal, commercial or institutional establishments. (European environmental agency report 2013, Pp 7.)

To further substantiate the objectives of this thesis, the research was carried out in relation to CONNECT project. The acronyms means the Co-creation of network modes for market entry in developing countries. It is a research project that is being carried out by Lahti University of Applied Sciences, Laurea UAS and Hämellina UAS, with main objective of supporting growth and speeding up internationalization of Finnish Renewable Energy (RE) Small and Medium Scale Enterprises (SMEs) to developing countries through sustainable networks.

Renewable energy is energy generated from natural resources which are replenished constantly by nature; these includes sunlight, wind, rain, tides, and geothermal heat. The popularity of renewable energy can be linked to the growing trend of environmental concern and the diminishing status of reserves of conventional energy sources. (Mohammed et.al 2013, p 260-267)

2 BRIEF HISTORY OF ENERGY SOURCES IN NIGERIA AND LAGOS

2.1 Energy Sources in Nigeria

The energy resources in Nigeria are crude oil, natural gas, coal, tar sand and renewable sources (biomass, hydro, solar, wind). Glaringly, the primary commercial energy sources remain crude oil and natural gas. They are the most developed sources of energy in the country. The current estimated oil reserve in Nigeria is 35.9 billion barrels, while the daily production capacity is 2.4 million barrels of crude oil. At this rate, the oil reserve will be depleted in 30-35 years period (Agbro & Ogie 2012, p 150-155).

According to shares of energy consumption in Nigeria below, the use of fuel wood/firewood is predominant in Nigeria, while the urban dwellers prefer kerosene, a derivative from fossil fuel. Those who live in the rural regions utilize biomass in the form of fuel wood and agricultural wastes, though most trees are fell indiscriminately to cater for domestic chores. (Ojolo, Orisaleye, Ismail, Oduntayo 2012, p 513-516 S.J. et al. 2012)

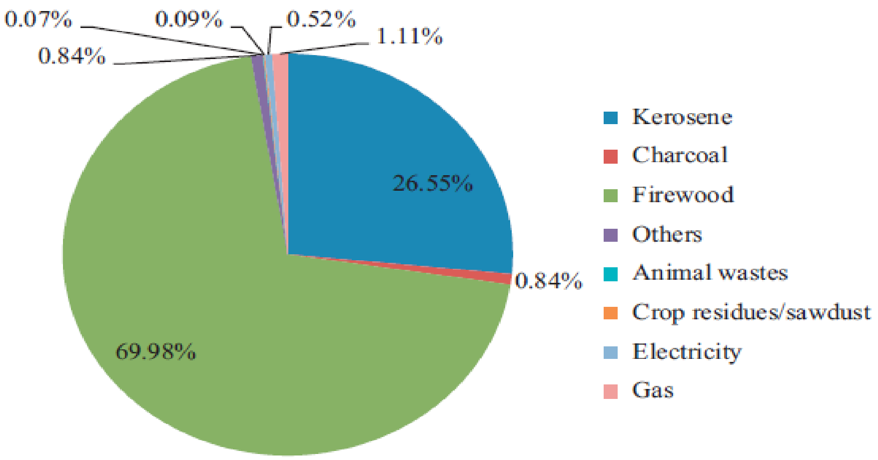


Fig 1 Shares of Energy Consumption by source in Nigeria (Mohammed et.al 2012)

Figure 2 below shows that the , The gross energy supply for 2005 was 105 MTOE with contributions coming primarily from oil (14 %), natural gas (7 %) and biomass (78%) and hydro (1%). (Agbro & Ogie 2012, p 149-155).

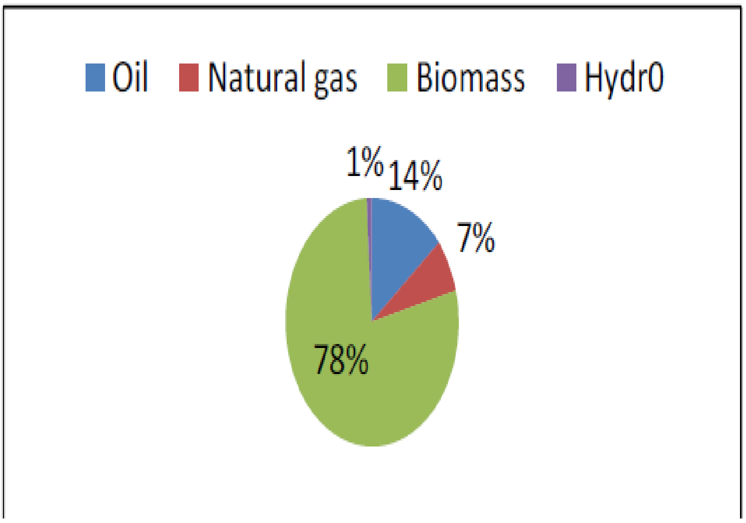


Fig 2 Nigeria Energy Supply for 2005 (Agbro & Ogie 2012)

2.1.1 Biomass resources in Nigeria

Biomass materials in Nigeria include aquatic biomass, wood, charcoal, grasses, shrubs, agricultural crops and waste (agricultural, forestry, municipal and industrial). Total biomass potential in Nigeria that consists of animal, agricultural waste, and wood residues, was estimated to be 1.2 PJ in 1990 (Obioh and Fabgenle, 2004; Agbro & Ogie 2012). Further research revealed that bio-energy reserves/potential of Nigeria are as follows: sixty one million tonnes /annum of animal waste, almost thirteen million hectares of fuel woodfuel wood, eighty three million tonnes/ annum of crop residues. (Agba, Ushie, Abam, Agba, Okoro 2010, 441-449).

Table 1 Biomass resources and estimated quantities in Nigeria for year 2004 (Sambo 2009, adapted by Author

Resource	Quantity (million tonnes)	Energy value (‘000 MJ)
Fuel wood	39. 1000	531.0000
Agro waste	11.2444	147.7000
Saw dust	1.8000	31.4333
Municipal Solid Waste	4.0750	

Looking at it from the point of view of land availability and the wide range of biomass resources, Nigeria has significant potential to produce biofuels and even become an international supplier. Some potential crops for biofuel production are cassava, sugar cane, rice and sweet sorghum for bioethanol; palm oil, groundnut oil, and palm kernel for biodiesel. Nigeria is the highest producer of cassava in the world, and has capacity for oil palm plantation, which can serve as a great source of biodiesel. (Abiodun 2007)

2.1.2 Exploring biomass in Lagos

Renewable energy sources like solar, biomass, wind, hydro, tidal, wave, ocean current and geothermal are generally abundant in Lagos, except hydropower due to absence of significant falling rivers whose gravitational force can be tapped. Generally, three out of all these are currently most attractive in the nearest future: biomass (including MSW), solar and wind.

The Lagos State Government is looking into ways of converting saw dust generated from its many saw milling plants into energy. Also, the government is actively investigating the possibility of using energy from renewable sources for its development projects, such as residential estates or industrial real estate like Lekki Free Trade Zone.

The high demand of electricity consumption in Lagos state is mostly procured from :

1. Fossil fuels sourced power that uses natural gas and is produced from Independent power producers,

2. Diesel powered self-generating facilities.

However, Lagos is set to reverse the trend from 2013 onwards by proposing to procure its power requirements from verifiable renewable sources, with a target of 2.5 % by the end of 2013, 5% by the end of 2014, 15 % by the end of 2016 and 30 % by 2020. (Lagos State Ministry of Energy & Mineral Resources 2012)

2.2 Lagos within the global view

During the United Nations conference on Sustainable Development(Rio+20) on 19th June 2012, the Climate and Clean Air Coalition (CCAC), the Clinton Climate Initiative/C-40, the World Bank and the Global Methane Initiative launched a partnership in order to establish a platform for sharing experiences from successful cities to others around the world.

Landfills are the third largest man-made source of methane, a greenhouse gas over 20 times more potent than CO2, and municipal waste production is expected to nearly double worldwide by 2025. The partnership will work with a group of leading cities, including Lagos and New York to design city-friendly strategies for rolling out the initiative. (UNEP 2012- Clean Cities, Clean Climate: Launch of Solid waste Partnership.)

In the quest of creating a healthy urban environment, the World Bank is involved in financing urban landfill gas collection with energy recovery and composting projects. The bank is developing methods of avoiding methane production through recycling methods. In the carbon finance area, it has 38 municipal waste management projects plus additional projects for agricultural wastes (WMW 2013).

3 LAGOS: GEOGRAPHY, DEMOGRAPHICS, AND ECONOMICS

3.1 Lagos and its unique attributes

Lagos is one of the mega cities in Africa , and is located in South Western Nigeria on the west coast of Africa, within latitudes 6°23' N and 6° 41' N and longitudes 2° 42' E and 3°42' E, as shown in Fig 3 below. It comprises of 70 square kilometers of the former Federal Territory, which was composed of the geographically formed islands of Eko (Lagos Island), Ikoyi, Victoria Island, Iddo-Otto, Ijora and Apapa. The central and most developed part of this island chain is Lagos Island. It also incorporates the municipal settlements of Ebute Metta,Yaba, Surulere, Tin-Can Island (Mekuwen) and the Eti-Osa areas, which all together cover 85.53 square kilometers. Lagos houses approximately 70 per cent of all Nigeria’s industries (UN-Habitat 2008b).

Fig 3 Map of Nigeria (Nigeria Muse, 2010.)

3.1.1 Lagos population and urban structure

The Lagos state is the smallest state in Nigeria, with an area of 356,861 hectares of which 75,755 hectares are wetlands. Yet it has the second highest population, which is over 5% of the national estimate. The state's population according to the 2006 census was 9,013,534 out of a national estimate of 140 million (National Population Commission, 2007).

The present rate of population growth is about 275,000 persons per annum with a population density of 2,594 persons per square km. In a United Nations study of 1999, the city of Lagos was expected to hit the 24.5 million population mark by the year 2015 and thus be among the ten most populous cities in the world (Lagos State Government, 2006).

About 53% of all manufacturing industry of Nigeria is located in Lagos. It accounts for 62% of gross industrial output and 61% of the total national industrial value added. It houses approximately 70 per cent of all Nigeria's industries (UN-Habitat 2008b). The city generates between 9,000 - 10,000 metric tons of waste per day, and waste generation per capital is put at 0.5kg/person/day. (Olubori 2011)

The city has most of the important entry points into Nigeria, Sea: Apapa and Tin Can Ports, Air: Murtala Muhammad International Airport and Land: border with Republic of Benin. (Lagos Ministry of energy and Mineral Resources, 2012). Due to the small land area and the surge in Lagos population, there has been an acute shortage of housing: the increase in Lagos population accounts for 5 million deficit in housing, which has led to increase in the number of slums from 42 in 1985 to over 100 in 2010. (Oshodi 2010)

3.2 Past and present practice of waste management in Lagos

The search for a solution to the waste problem in Lagos has a long history. The responsibility of managing solid waste was transferred from the Local Governments to the State in 1977. This led to the establishment of Lagos State Refuse Disposal Board, later renamed Lagos State Solid Waste Disposal Board and, presently, Lagos State Waste Management Authority (LAWMA), with each change in name accompanied by modified policies aimed at providing better urban waste management services.

The emergence of LAWMA led to the involvement of the private sector in waste management. An estimated 255,556 tons per month of municipal solid waste is generated in Lagos (Ogwuleka 2009). This huge amount of waste will naturally put an enormous pressure on the environment.

Lagos Waste Management Authority (LAWMA) is responsible for the collection and disposal of municipal and industrial waste. The collection and transportation of MSW has been divided between the Lagos State Waste Management Authority and private sector participants. The latter focus on industries and commercial centers while the former collect waste from domestic sources. Other collection methods are quite informal, while some private households patronize unskilled people (cart pushers) that collect and transport the waste to the nearest landfill or dumping site.

The Lagos State Waste Management Authority has reduced the turn around time of household waste collection from daily to twice per week, due to the provision of the new and bigger waste bins for storage in most of the households, in a bid to improve all-round efficiency in waste collection.

According to a field research of the Agege area of Lagos which generates one of the largest quantity of urban waste, 90.4 percent of the residents have access to the private sector partnership programme of Lagos State Waste Management Authority. This has improved the general waste collection from many households (Idowu, O.B.A et.al 2011). Table 3 below compares the methods of waste collection in the past with the present situation.

Table 2 Method of Waste disposal among Lagos residents before and after year 2005. (Idowu et.al 2011. Re-adapted by Author)

Waste Collector	Before 2005 (%)	At Present(%)
Informar Cart Pusher	53.2	5.1
LAWMA	40.5	-
Private Sector Programme of LAWMA	-	90.4
Other Government agencies	1.3	-
Cart Pusher/ PSP	-	3.8
Street Dumping	3.8	-
Others	1.3	0.6

Based on the above data, LAWMA claimed to have achieved 89 % of efficiency in MSW collection, transportation and retaining confidence in public utility service, and projecting to reach the 98 % mark by 2015. (Oresanya 2011.)

The Lagos State Government, in order to improve solid waste collection and disposal, recently opened two Transfer Loading Stations (TLS), which are expected to receive waste collected from collection trucks in the Lagos business district, which comprises 10 local council areas. The TLS has a maximum handling capacity of 1000 metric tons (equivalent to 33 truckloads) of waste per day (LAWMA 2012). The waste is now transferred to dump sites. This method has improved turnaround time of collection trucks and reduced traffic congestion significantly.

Recently, a composting facility has been set-up by a private company, Earth-Care Nigeria Limited in Odogunya, Lagos. It has capacity to process 1500 tons out of Lagos municipal waste per day, out of which high quality compost can be produced for sale to farmers within Lagos and environs. (Allafrica 2009).

3.3 Brief Comparison of Lagos Waste Management Authority (LAWMA) with Päijät Häme Waste Disposal Limited

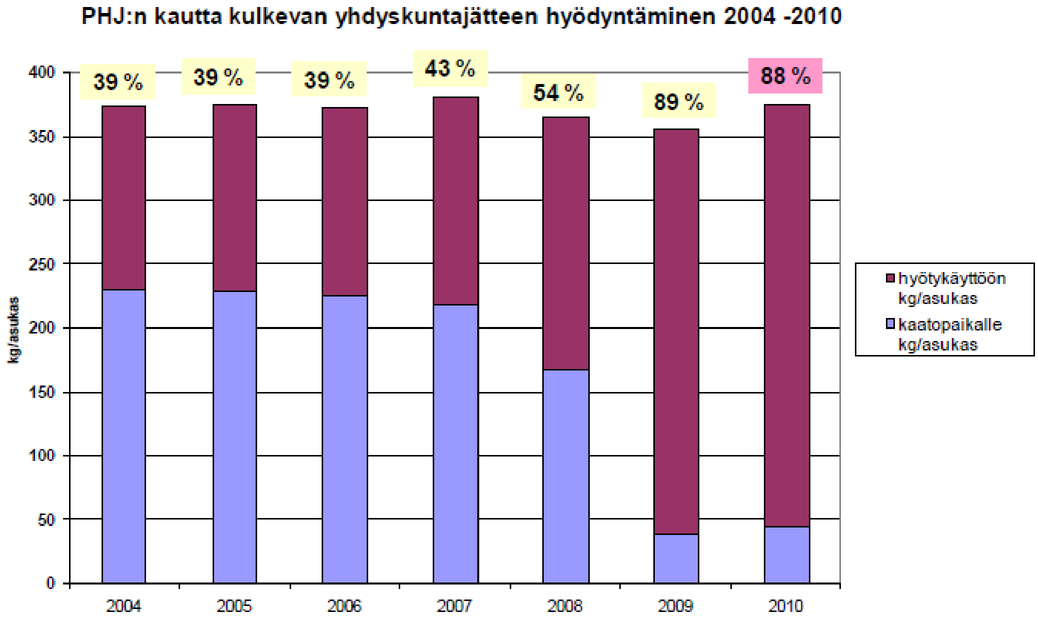
The Päijät Häme Waste Disposal company founded in 1993 . It is jointly owned by twelve municipalities . It serves a population of 202, 000 residents with its 30 regular personnel.

The Kujala Waste Treatment Centre in Lahti is the main site of the company. The waste centre receives waste from communities and has production facilities for interim storage, handling, recovery, transfer and final disposal. Figure 4 below shows the aerial view of the site, which covers 70 hectares in total, with 8.3 hectares of landfill currently in use and 23 hectares of decommissioned landfill. Approximately 5.3 hectares is used for receiving and storing of recyclable waste. Two hectares are used for treatment of contaminated soil, with a composting facility accounting for approximately 5 hectares. The center receives approximately 200,000 tones of waste each year. Over 90 % of waste received at the centre is reclaimed. (Päijät Häme Waste Management Ltd. 2011.)

Fig 4 View of Kujala Waste Center (Päijät Häme Waste Management Ltd. 2011)

The centre has been producing biogas from waste since 2002 from the thirty-three gas wells located in the old landfill area. The pumping station has a capacity of 800m3/hr, which produces approximately 2MW of electricity that heats almost 1000 single family homes. (Päijät Häme Waste Management Ltd. 2011)

Table 3 Quantity of waste utilized and landfilled by PHJ. Hyötykättön is translated as utilization and Kaatopaikalle as Landfill in English language (Author). (Päijät Häme waste management Ltd. 2011)



The above Table 3 indicates the progress achieved by the Päijat Häme region in utilizing and turning waste into useful resource. There has been a steady increase of utilized waste from 39 % in 2004 to 89 % and 88% in 2009 and 2010 respectively. At the same time the quantity of refuse disposed of on landfill has reduced from 200+ kg/ client in 2004 to less than 50kg / client in 2010. The company achieved 75 % of recovery in 2010 and is now projecting to achieve 80% in 2016, in accordance with the national objective.

Because of physical differences of the two different locations, this research work cannot make outright comparison because Päijät Häme waste management company serves about five hundred thousand residents, while Lagos waste management serves a population of more than fifteen million.

Nevertheless, the process, growth and development of Päijät Häme waste management Ltd is a good example of sustainability in waste management practice, based on two cogent factors shown in Table 4 above.

a. Utilization: Most data from Lagos waste management relates to the collection and transportation activities. Not much has been achieved as regards waste utilization. According to the Table 4 Päijät Häme waste management Ltd has moved beyond efficient collection to 88 % waste utilization.

b. Landill Deposit. Most of the waste collected by Lagos State waste management authority are being dumped on various landfill sites (Aluko 2012), while Päijät Häme waste management Ltd (PHJ) has gradually reduced its landfill waste disposal from 200+ kg/ client in 2004 to less than 50kg/client in 2010, and it further generates electricity from the landfill gas collected from the dumpsites within its vicinity, as shown in Figure 5 below.

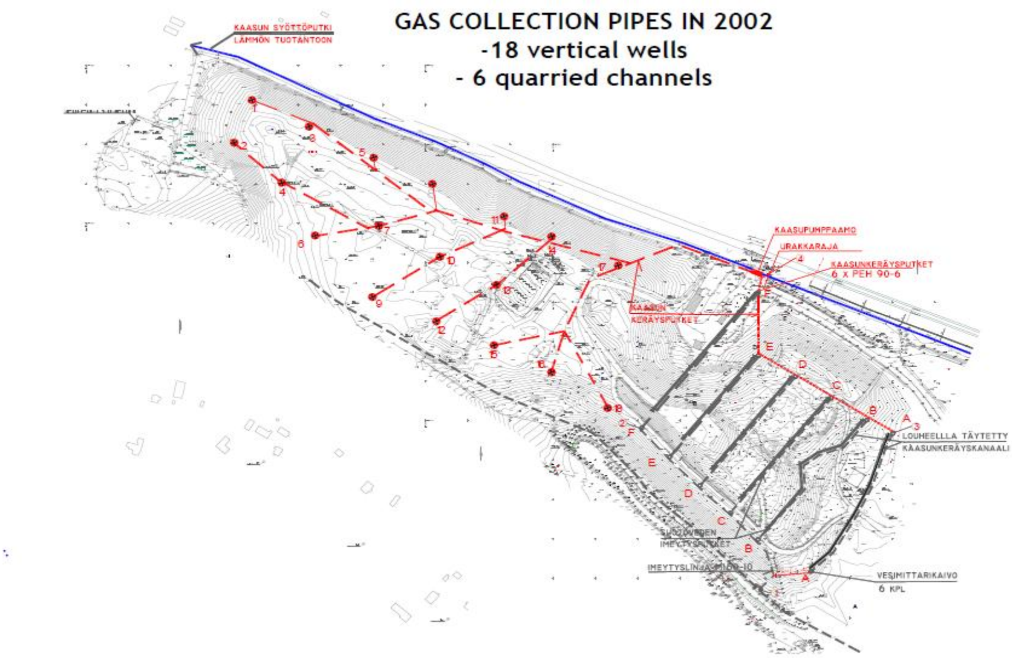


Fig 5 Network of gas collection pipesk at Kujala Waste Center (Päijät Häme waste management Ltd, 2011)

3.4 Brief comparison of Lagos waste management with Accra waste management

The population of Ghana is estimated to be about 24.7 million with a yearly growth rate of 1.822 %. There are 10 regions, 49 main cities and 166 districts in Ghana. According to the 2011 census, out of the total of Ghana's population of about 24.7 million, about 12.62 million (representing 51.1%) are found dwelling in the urban areas. This is however projected to increase by 3.4% every year. (Ghana Statistical Service 2010)

The country is also faced with rapid urban growth and industrialization. In 2010, the average amount of waste generated was 0.51 kg per capita per day with annual waste generation capacity of about 4.5 million tons. Only 10 % are managed well through proper incineration and land filling. As shown in Table 5 below, Accra, which is the capital, ranks highest in waste collection efficiency, with almost 85% collected to various landfills. (Ofori-Boateng 2012.)

Table 4 MSW generated in Ghana's Main Cities **(** Ofori.Boateng et. al 2012, adapted by Author)

	Quantity of MSW generated per day (x10^3 tons)			
Metropolitan center	Year 2004	Year 2007	Year 2010	Collection efficiency (%)
Accra	1.25-1.90	1.50-2.20	3.00-3.80	80-85
Kumasi	0.85-0.90	0.95-1.01	1.50-2.10	65-70

Takoradi	0.70-0.85	0.90-1.00	1.30-2.50	60-65
Tamale	0.40-0.60	0.70-0.85	1.09-1.20	50-60
Average Total	3.780	4.555	8.127	

The highdense population in the urban areas tends to place huge burden on the environment because the uncollected waste are disposed of inappropriately. MSW forms about 80% of the total wastes generated in Ghana, with their organic matter content estimated to be about 68% . Fig.6 below shows the main compositions of MSW generated in Ghana in 2010.

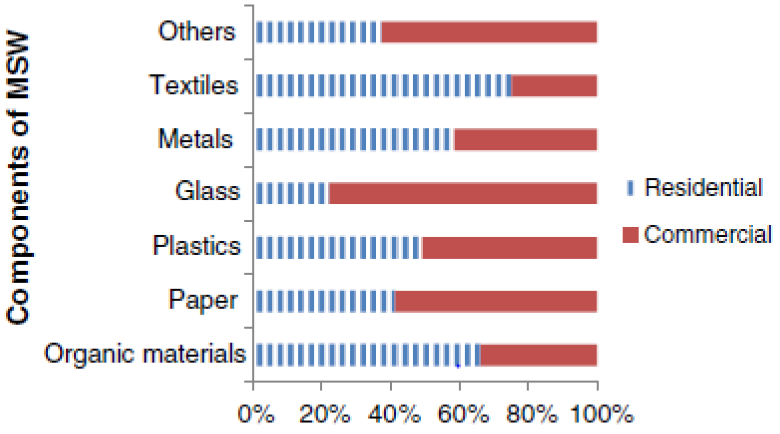


Fig 6 Composition of waste generated in Ghana. (Ofori-Boateng et.al 2012)

The composition of MSW largely depends on factors such as lifestyle, cultural tradition, economic status, literacy rates, food habits, and climatic and geographical conditions .

In comparison, though both Lagos and Accra have high collection efficiency of 90% and 85 % , Lagos has achieved 12 % conversion of its waste to useful resources through the establishment of a composting center at Ikorodu area in Lagos, to handle some its organic waste, and the plastic and paper recycling units in LAWMA. (Oresanya 2011). While the sorting of MSW into various categories is not yet common in Ghana, this makes it quite challenging for proper recycling and composting.

4 BUSINESS POTENTIALS: UTILIZING LAGOS MSW, LANDFILLS AND SAW DUST

There are opportunities for investment in all areas of waste management in Lagos, and private investors are needed due to the high cost of procuring and maintaining the equipment and personnel. Some of the specific opportunities identified by the state government include waste conversion, waste transfer loading stations, compactors, wheeler bins, motorized street cleaners and waste transfer loading station. Because of the increasing population and urban expansion, Lagos needs 14 waste transfer loading stations but it can only afford two presently. The government desires the investment of the private sector in this regard. The city needs 450 waste compactors for efficient transport of waste but with the cooperation of the private companies, only 200 are in use now. Approximately 375 kilometers of road needs regular street cleaning, but the waste management authority lacks both human capacity and equipment to carry out this task. The Lagos state waste management authority is willing to involve private companies for the task. (LAWMA 2011.)

4.1 Lagos municipal solid waste

Millions of tonnes of waste are collected each year with most of it ending up untreated in open landfill dumps and lagoons. The content can be categorized into plastics, textiles, paper, glass, metal, wood, and other organic waste. The biomass resource in MSW includes the putrescible, paper, and plastic. These can be converted into energy by direct combustion, or by natural anaerobic digestion in the landfill. The biogenic fraction of MSW can be anaerobically stabilized in a high rate digester to obtain biogas for electricity or steam generation. (Agbro & Ogie 2012). The inspiring trend in the world of technlogy has provided various means of generating electricity from MSW. Briefly, the three major methods are: gasification, anaerobic digestion and incineration.

It is advisable that sorting of organic and and inorganic components of the waste should be carried out at the initial stage. This will make the recycling process easier and separates the heavy components that are inorganic in nature. The organic components are converted into energy mostly through biologcal/chemical processes, while the inorganic may be burnt directly as refuse derived fuel (RDF) in an incineration energy production plant for electricity or heat production (Agbro & Ogie 2012).

Stored wastes are collected from house-to-house, communal depots, kerb sides, block system of collection, commercial and industrial waste collection and bulk loading. The various means of transfer to disposal sites in Lagos include carts, open bed trucks, closed trucks and compactors. Recycling of materials such as paper, plastics, glass and metals considered to have high market value is usually carried out by scavengers who separate these from the waste either at source or at landfill sites and then sell them.

Generally, wastes are not treated; most waste is transferred to the landfill sites where they are openly burnt. Lagos has two incineration plants, which have never been used, being capable of treating only wastes containing less than 20% water, while waste in Lagos generally contains 30–40% liquid. As can be seen from Figure 7 below, that composes of 45% vegetables.

The composition of MSW from Lagos is putrescible, paper, plastic, textile waste, vegetables, metal, glass, and others. (Jeleel 2011.)

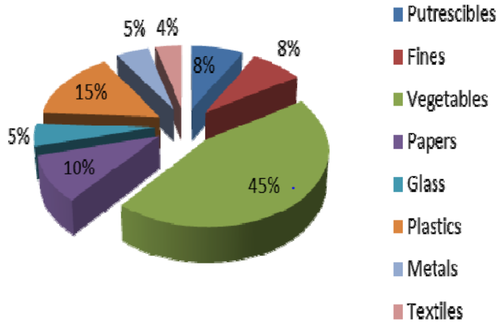


Fig 7. Waste Characterization in Lagos Metropolis (Jeleel 2011)

Table 5 Classification of general waste in Lagos metropolis (Adapted from Mohammed et. al 2012)

Source of waste	Description
Households	Vegetables, biodegradable kitchen waste, rags, animal bones, common floor refuse, useless packages
Commercial centers	Vegetable wastes, fruit wastes, plastics, metals, polythene bag waste, package papers, textiles, cardboard, waste tyres, food waste, papers, slaughter waste, animal bones, sweeping refuse
Institutions	Printed papers, cardboards, packaging wastes, hospital wastes, garden waste

Industries	Agro-processing waste, plastics, discarded metals, packaging waste, chemical waste, wood waste, food processing waste

4.1.1 Estimated energy generation potential of Lagos MSW

The MSW for the Lagos metropolis is estimated to be 0,63kg/capita/day . This value is believed to be true because most studies on MSW resulted in figures between 0.6-0.8kg as capita/person/day. (Ogwueleka 2009, p 173-180).

Mohammed et.al (2012) calculated both the energy and power potental that can be realized from incineration of MSW, using an average calorific value that is generally accepted for most developing countries. The formula is as follows:

Ep = HV x W x 0.0011628

Pgp = Ep/24

where Ep = Energy Potential

HV = Calorific value of the waste (kcalkg-1)

W= Weight of the waste (ton)

The MSW calorific value to use for the purpose of this thermo-chemical conversion (incineration) is 905kcal/kg.

Most of the resource and energy recovery potential from MSW through the thermo-chemical conversion depends on the quantity, physical and chemical characteristics of the waste components. Using the bio-chemical conversion process for MSW is subject to the biodegradable component of the waste. (Rao et al. 2010.)

Table 6 Estimated power generation potential from MSW within Lagos Metropolis (Mohammed et.al 2012)

Local Government Area	2006 Population	MSW Generation (ton/year)	Energy Recovery Potential(MWh)	Power Generation Potential(MW)
Agege	1,033,064	650.83	685	28.5
Ajeromi-Ifelodun	1,435,295	904.24	953	37.7
Alimosho	2,047,026	1,289.63	1357	56.5
Amuwo-Odofin	524,971	330.73	348	14.5
Apapa	522,384	330.73	348	14.5
Badagry	380,420	239.66	252	10.5
Epe	323,634	203.89	215	9.0
Eti-Osa	983,515	619.61	652	27.2
Ibeju-Lekki	99,540	62.71	66	2.8
Ifako-Ijaiye	744,323	468.92	494	20.6

Ikeja	648,720	408.69	430	17.9
Ikorodu	689,045	434.10	457	19.0
Kosofe	934,614	588.81	620	25.8
Lagos Island	859,849	541.70	570	23.8
Lagos Mainland	629,469	396.57	417	17.4
Mushin	1,321,517	832.56	876	36.5
Ojo	941,523	593.16	624	26.0
Oshodi-Isolo	1,321,548	832.56	876	36.5
Somolu	1,025,123	645.84	680	28.3
Surulere	1,274,362	802.85	845	35.2
Total	17,552,942	11,058.35	11614	483

4.1.2 Challenges of waste management in Lagos

Just like most mega cities in the world, there are significant challenges towards effective waste management in Lagos. Below are some factors that are responsible.

Population

Lagos is the most densely populated city in Nigeria, due to its strategic location and industries. The effect of increasing population on waste management is very significant. It affects the collection, disposal and treatment. According to Nigeria

Population Commission (2006), the population of Lagos rose from 1,443,569 in 1963 to 5,685,981 in 1991 and to 6,947,191 in December 1996. The latest count in 2007 puts it at over 9,000,000. This has impacted negatively on both the environment and waste management. Waste is being generated according to the proportion of population. Lagos is being faced with the twin problem of population increase and rapid expansion.

Waste disposal attitude of Lagos residents

Individual attitudes to waste disposal in Lagos are almost worse than any other contributing factor. Cases where dumpsites that have been closed to the public are being continuously used by the people do not augur well for effective waste management. Some illegal dump sites are being created and used by residents, posing a lot of health hazards and aesthetic loss to the environment. (Adewole 2009.)

Inadequate equipment, technologies and personnel

Right from the beginning of waste management practice in Lagos, the state has a long history of inadequate equipment for collection of wastes at numerous points all over the states. The coordinating agency lacks the technical knowhow of the fleet of trucks used, which leads to frequent breakdowns. The total number of vehicles required in the 20 local government area of Lagos are 757 but less than 200 exist now. (Adewole 2009). All the wastes deposited at designated points of collection are not being transported to the transfer station adequately, leading to heaps of refuse polluting the environment.

Also, most personnel operating the equipment are not well trained. Lack of funds prevents overseas training that should be part of the human capital development.

Corrupt practices

Corruption is a character deficiency that has eaten deep into almost all the administrative systems in the Nigerian society. Beyond Lagos, the collapse of most public funds can be traced to corrupt employees. It has been reported in some instances that shop owners in market places have to bribe Lagos State waste management operatives before their wastes could be collected. Banned truck pushers have been identified to be conniving with corrupt agency staff to create illegal dumpsites to the detriment of the environment. (Adewole 2009.)

Overlap of functions by Government agencies

Overlapping functions can create some confusion among the citizenry, because more than one government agency in Lagos lay claims to the protection of the environment. Examples are Lagos State waste Management Authority, Lagos Environmental Protection Agency and the police. These types of situations will not augur well for effective waste management. Any effort towards a sustainable legal framework for successful enforcement must seek to avoid the overlap of environmental duties of concerned employees, in order to take positive steps towards effective waste management.

Technology adaptation

The waste sector being a specialized industry, a customized technology for Lagos weather condition will therefore be needed since it is a coastal city, an engagement with the local sector requires in-depth experience, research and technical know-how. The efforts to apply proven technologies in any local conditions should not be underestimated. The applied technology must suit the composition, quantities and qualities of waste that will be delivered to the processing plant, as well as the local climatic conditions, and there must be a potential demand for products derived from the waste. (Olubori 2011.)

Environmental and social factor

Waste management projects include significant environmental, health and safety risks that are linked with the process of collection, treatment and disposal of waste. The existence of unskilled waste pickers and the dangers they are exposed to are worthy to be considered in solving the problem of waste management in Lagos.

Lack of regulatory, financial and legal framework

The public institutions in developing countries often fail to provide the necessary requirements to ensure a proper and sustainable transfer to the private sector (Busse 2010). This is applicable to the scenario in Lagos where the private sector is being utilized to perform most of the waste management tasks. There are no appropriate systems of monitoring and control, or relevant skills at the respective government agency.

Developing countries spend around USD 46 billion annually on MSW management, but it is estimated that they should spend another USD 40 billion to cover the service delivery gap. 'Considering the projected increase in MSW generation, their financing needs could surpass USD 150 Billion by 2025'. (Le Courtois 2013.)

Considering the customization and the standard of technology needed in controlling Lagos waste, it can take up to half of the municipal budget. This means that that stringent measures should adopted to check the gap among MSW costs, availability of funding and proposed growth in population (including waste generated). The Lagos government must enhance their service efficiency, support research in waste sector, evaluate the involvement of private sector in energy sector development and access other international sources of funding.

Waste to power initiatives

Though the Nigerian electricity sector has been liberalised by the Electric Power Sector Reform Act of 2005, and a regulatory institution, the Nigerian Electricity Regulatory Commission (NERC) was established, inadequate incentives for renewable energy development can lead to high electricity tariffs for consumers. This is a major challenge that requires indepth research, policy formulation and implementation to recommend a feasible incentive model.

4.2 Unused sawdust at Okobaba sawmill

The large quantity of sawdust produced daily at saw mills is worthy to be considered as an untapped bio energy source. One major initiative with good potential is Okobaba saw mill. Identified barriers are lack of proper disposal methods and lack of relevant technology to commercialize the saw dust produced as a result of wood processing activities within the saw mill community (Dosumu, O.O 2002).

The mill was established in the 1940's in a riverine community on the Lagos Mainland, located on an expanse of land, measuring up to 25 hectares. The aerial map showing its location beside the lagoon can be viewed in Figure 8 below. It is believed to be the second largest saw mill community in Africa and the largest in West Africa. It is a rallying point for all users of wood and related forest products (Ogunleye & Sewanu 2011).

Fig 8: Aerial Map of Okobaba Community indicated by the yellow polygon (Sewanu & Ogunleye 2011)

4.2.1 Briquette production

Briquetting is a way to convert loose biomass residues such as sawdust, straw or rice husk, into high density solid blocks that can be used as fuel. Biomass briquettes can replace fossil fuels and wood in industrial processes and domestic uses. The best materials for high pressure briquetting are sawdust and other woody residues, because these contain a high proportion of lignin. (Furlord 2013). They are cleaner and easier to handle than ordinary fuel wood, and cut greenhouse gas emissions.

There are two methods of production, Both methods require the loose biomass to be ground to a coarse powder like sawdust, which is already available in large quantities at the Okobaba sawmill. The low pressure briquette production can be used for materials with a low amount of lignin such as paper and charcoal dust. The powdered biomass is mixed into a paste with a binder such as starch or clay, and water. A briquetting press is used to push the paste into a mould or through an extruder, or it can simply be shaped by hand. Due to the subject of this research work, the study is limited to high pressure production only.

High pressure briquetting uses a power-driven press to raise the pressure of dry, powdered biomass to about 1500 bars (150 MPa). This compression heats the biomass to a temperature of about 120°C, which melts the lignin in the woody material. The press forces the hot material through a die at a controlled rate. As the pressure decreases, the lignin cools and re-solidifies, binding the biomass powder into uniform, solid briquettes. Both the shape and size can be controlled through fitted molds attached to the machine (Ashden 2013). Below are some diagrams for high pressure briquette production. Briquettes have high specific density (1200 Kg/m3) and bulk density (800 Kg/m3) compared to just 60 to 180 Kg/m3 of loose bio coal. (Bio Coal 2009)

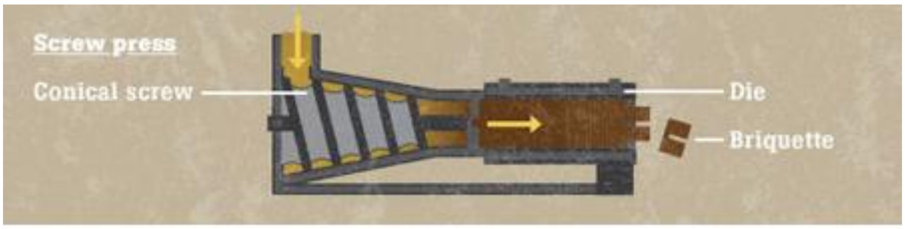


Fig 9 Screw Press Briquette Production Machine. (Asden 2013)

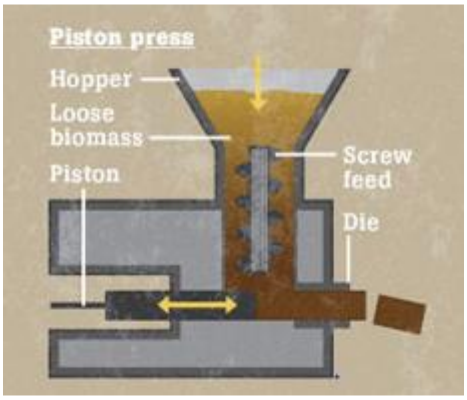


Fig 10 Piston Press Biquette Production Machine (Ashden 2013)

4.2.2 Bio coal technology

Wood and briquettes can be further upgraded to produce less smoke during combustion and a relatively faster rate of combustion. Bio coal is a type of solid bio-enrgy fuel derived from heating of biomass in the absence of oxygen. The process converts biomass to solid fuel, which either produces torrefied wood if the operating temperature is between 230-280 ^{o} C, or a charcoal if the operating temperature is more than 300^{o} C. Both products can be generally refered to as bio-coal. (Baltic Bioenergy and Industrial Charcoal 2013.)

Bio-coal is a non conventional source of energy, renewable in nature, eco friendly, non polluting and economical. It does not require adding any binder / chemicals so it is 100% natural. (Bio Coal 2009.)

Table 7. Heating value of some wood based solid fuels and coal. (Baltic bio-energy and industrial charcoal 2013, adapted by Author)

	Processing temperature (°C)	***Heating value (MJ/kg***
Untreated wood		18
Torrefied wood	230	18.5
	250	19
	280	22
Charcoal	> 300	28-33
Coal		15-31

4.3 Recovery potentials from Lagos landfills : Olushosun landfill as a case study

4.3.1 Categories of Lagos landfills

There are 3 major landfills and 2 temporary sites serving Lagos State.

Olushosun Landfill Site: Situated in the northern part of Lagos at Ikeja Local Government and receiving approximately 40% of the total waste deposits from Lagos. The size is 42.7 hectares and the residual life span is 20 years.

Abule-Egba Landfill Site: The site occupies a land area of about 10.2 hectares in the western part of Lagos in Alimosho Local Government and receives waste from a densely populated area. The residual life span is approximately 8 years.

The Solous sites: Each site receives an average of about 2,250 ^{m3} of waste daily.

a) Soluos II - is on 7.8 hectares of land with average life span of 5 years.
b) Soluos III- a new site with approximately 5 hectares of land with average life span of 5 years.

Satellite sites

These Satellite Sites comprise Owutu (Ikorodu), Sangotedo (Eti–Osa) and Temu (Epe) dumpsites. These sites serve as backups for other three main landfill sites, and also have an advantage of proximity. They are temporary sites, and receive an average waste of about 1,864.29 m3 per day.

Out of the three major landfills and two temporary ones, only two are being utilized for landfill gas extraction and composting (Aiddata 2010).

4.3.2 Physical characteristics of Olushosun landfill

The landfill area covers approximately 47 hectares. The waste depth is about 15m. The subsurface geology is comprised of a lateritic cover with variable thickness averaging 4 m. It is reddish brown in color with sand and clay portions. This cover overlies an alternating sequence of sand and clay deposits. The top soil (0-50 cm) and sub soil (50-100 cm) are predominantly clay and slightly alkaline with a PH range of 7.12-7.24. (Oresanya 2011). Figure 11 below shows the layout plan of the landfill site.

According to a recent article in Helsinki Sanomat of October 2013 , Olushosun landfill receives the largest amount of electronic waste in Africa. It supports almost a thousand scavengers that search the dump sites daily for recyclable components. (Matti Koskinen 2013.)

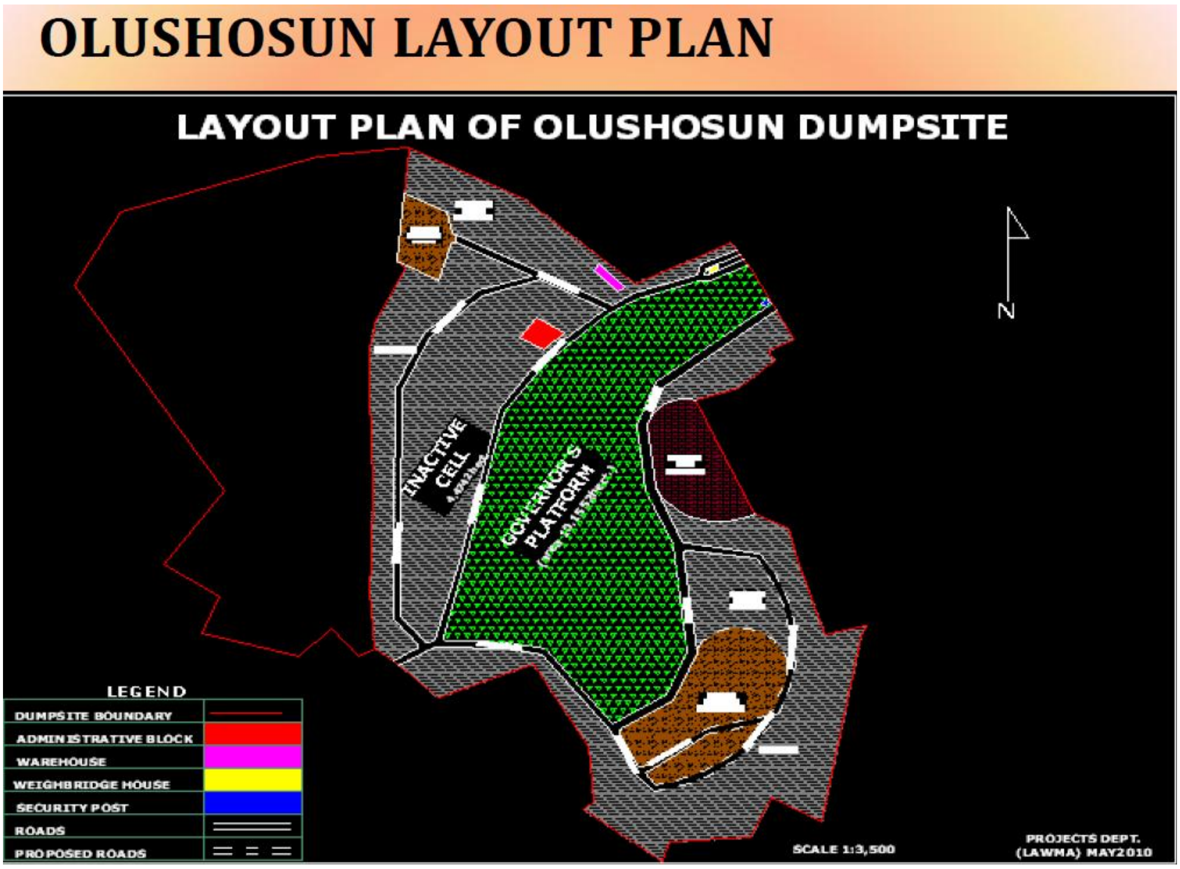


Fig 11 Layout plan of Olushosun landfill.

According to LAWMA monthly report of January 2013, Olusoshun Landfill received 196, 521.84 metric tonnes of waste, while solous II and III received 49, 993.35 and 57,020.36 respectively.

On a general note, the gas produced at landfills by natural decomposition of biodegradable waste is approximately 50% methane, 50% carbon dioxide and other gaseous components. Methane, a by-product of the decomposition of the organic biomass portion of solid waste disposed of in a landfill, is a greenhouse gas, which has 21 times the global warming potential of carbon dioxide (CO2) . The methane from landfills can be collected, scrubbed and cleaned before feeding into internal combustion engines or gas turbines to generate heat and power.

Total anthropogenic (human induced) methane emissions represent about 15 % of greenhouse gases. Worldwide, waste disposal accounts for more than 12 % of anthropogenic methane, which makes waste disposal the fourth largest source of non-carbon dioxide greenhouse gas. (Ludwig & Dielehman 2012)

According to the U.S. Environmental Protection Agency's Landfill Methane Outreach Programme (LMOP), the direct use of landfill gas (LFG) as an energy source for boilers, furnaces, heaters, kilns and other types of process operations is equally important as other renewable energy sources because it reduces global methane emissions and shifts energy resources away from fossil fuels. (Ludwig & Dielehman 2012.)

Also, the direct use of LFG for steam production is more efficient when compared to electricity generation from LFG. This can be a good option for numerous industries that use steam to power their engines for production in Lagos. Most boilers designed for LFG use between 80% and 90 % of the energy content of the methane gas, whereas only about 30 % of the energy value of the gas is converted into electricity if the same quantity of gas is used for power generation (Ludwig & Dieleman 2012).

4.4 Energy stakeholders in Nigeria

4.4.1 The Energy Commission of Nigeria

The Energy commision of Nigeria (ECN) is the main organ of the Federal government charged with the responsibility for the strategic planning and coordination of the nation's policies on energy in all its ramifications, including monitoring and evaluation of their implementation. The body serves as a centre for gathering and dissemination of information relating to national policy in the field of energy.

Also, the body advises the government of the Federation or a State on questions relating to energy. It prepares master plans for the balanced and co-ordinated development of energy in Nigeria after consultation with such agencies of government whose functions relate to the field of energy development or supply as the Commission considers appropriate. (Energy commission of Nigeria 2013)

4.4.2 Federal ministry of environment

The Federal Ministry of Environment was established in 1999 to ensure effective coordination of all environmental matters. One of the main objectives is to view the protection of the environment as a necessity to the achievement of the objectives of the country's socio-economic reforms.

Also, in other to be in tune with recent global environment developmental issues, the Federal Ministry established a special renewable energy unit with the objective to develop and implement strategies that will achieve a reliable clean energy supply and establish mechanism to develop the sector based on international best practices to showcase viability for private sector participation.

The unit will support renewable energy projects that will reduce projected national energy use by 20% by 2020.

4.4.3 The Lagos state Government roles

The Lagos state government coordinates all the stakeholders, including investors, consumers, donor agencies, non-governmental organizations, and civil society organizations. Lagos state is ready to promote and facilitate the development of projects that can take advantage of the framework for accessing international funds through the Global Environment Facility and the Clean Development Mechanism, taking the advantage that Nigeria has ratified the United Nations Framework Convention on Climate Change and acceded to the Kyoto Protocol. (Lagos Ministry of Energy 2012.)

The table below briefly lists the Lagos state government agencies and the roles they can play in developing renewable energy within Lagos metropolis.

Table 8: Showing Lagos State agencies and their roles (Lagos Min. of Energy 2012) .

Lagos State Government Agencies	Roles
Ministry of Energy & Mineral resources	Formulating and implementating of policies, Coordination of other ministries, Departments and Agencies of the LASG that are involved in the formulation of strategies and implementation of activities for the

	development of renewable energy in Lagos State. Establishing functional working relationships with relevant multilateral and bilateral organizations, like UN, world bank
Lagos State Electricity Board	Implementation of electricity projects
Ministry of Environment & its parastatal; Lagos State Waste Management Authority	Generating renewable energy initiatives, studying its effects on the environment, facilitating opportunities around MSW to energy projects, management of MSW within Lagos metropolis.
Ministry of Finance, Ministry of Economic Planning & Budget, and the Lagos State Board of Internal revenue	Designing and implementing all fiscal incentives proposed in Renewable energy policy.
Ministry of Justice & Office of the attorney-General	Providing the legislative and regulatory framework
Ministry of Commerce & Industry	Facilitating private sector incentives
Ministry of Science & Technology	Promoting and bridging home grown technologies and imported technologies.
Ministry of Rural Development	Focusing on renewable energy applications that improve the quality of life of the rural populace.
Ministry of Health	Focusing on renewable energy based health applications

Ministry of Transportation	Focusing on renewable energy based mass transit applications
Ministry of Physical Planning & Urban Development	Certifing home owners eligible for tax rebates based on adopted clean energy usage

The state government created a scheme called Lagos State Waste Management Partnership. The is the partnership arm of the Lagos Waste Managment Authority. The scheme was established to facilitate development of sustainable waste management by seeking partnership possibilities with international organizations, academic bodies, non-governmental organizations and related bodies. Also, the initiative was established towards promoting the integration of Africa into the rest of the developed world when it comes to sustainability development and modern waste management technology.

In actual sense, the scheme has been put to motion. Lagos Waste Management Authority is now acting as partners towards creating a sustainable waste management practice in Freetown (Liberia) and Accra (Ghana). As it seeks further development for Lagos waste management, it is also exporting the same practice to other African countries that have not reached its level of performance. (Integrity Reporters, 2013.)

4.5 CONNECT project model: A necessary intermediary

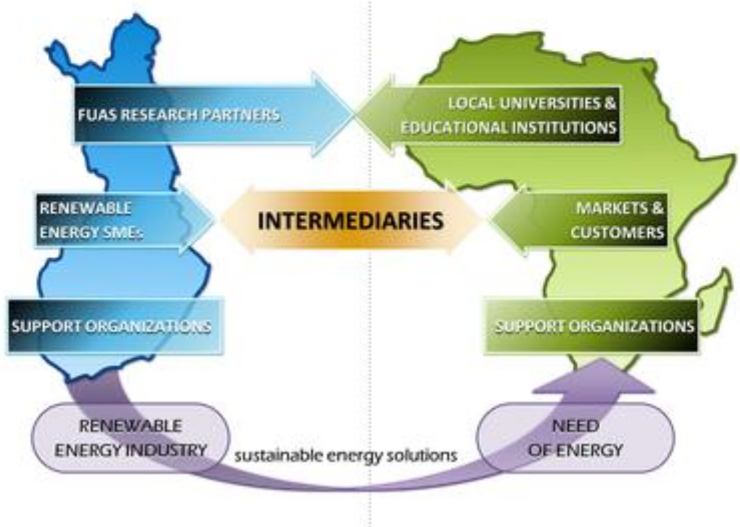


Fig 12 Schematic Diagram of CONNECT project model (CONNECT website)

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The sole objective of the project is to support the growth and facilitate the internalization of Finnish small and medium scale enterprises (SMEs) in the field of renewable energy to developing countries. Part of the project aims are to improve the abilities of Finnish SMEs to participate in value networks and cooperation between business and research partners, to open possibilities for new recruitments in renewable energy industry and intermediary companies and to co-create effective modes for network creation and utilize value potential of international students . (Laurea ammatikorkeakoulu-connect project 2013.)

The project is being funded by Tekes, the Finnish Agency for Technology and Innovation, and by Federation of Universities of Applied Sciences in collaboration with Laurea, Lahti and Häme Universities of Applied Sciences. (Aurela 2012,) In my opinion, an intermediary project like CONNECT will explore different avenues that will recommend a suitable model that fits the socio-cultural category of Lagos. Potential factors that may be considered for extensive waste utilization are the involvement of private sector in waste-to-energy technology development, feed-in-tariff, technology and equipment sustainability and human capacity development.

4.6 Doranova model for Zambia

In the course of conducting this research, an interview was conducted by the Author and Maarit Virtanen of the CONNECT project with Jarno Laitinen of DoraNova (a Finnish company) on the 23rd of July 2013. He is experienced in the industry of renewable energy and technology transfer from Finland to other countries including Zambia in Africa. He was able to shed more light on related technological approach, project scope and feasibility studies that may be needed for a city that has similar characteristics with Lagos. (Virtanen 2013).

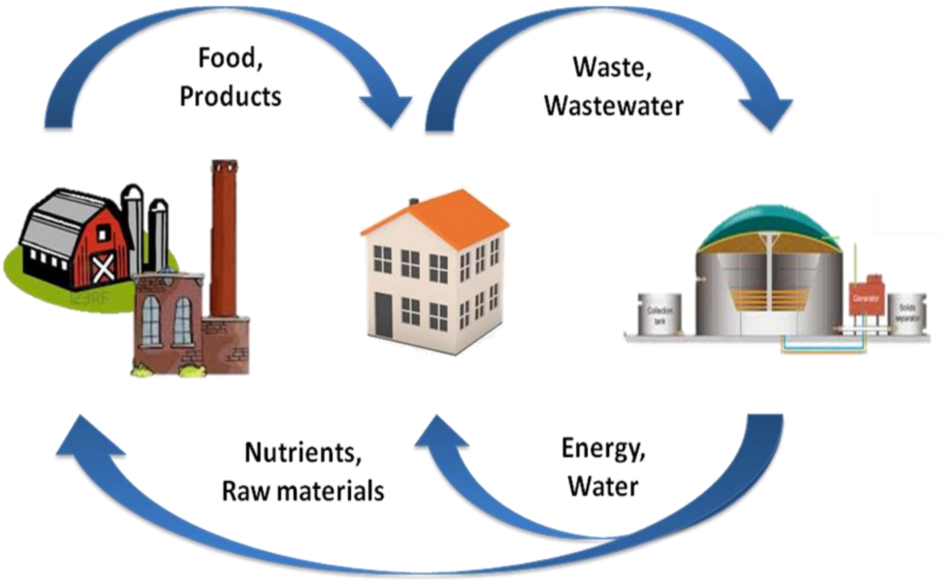

Fig 13 Doranova Waste to Energy Cycle (Laitinen 2013)

Just like Lagos, Zambia is deficient in energy supply, and seeks to develop its economy. Doranova designed a model, seen in Fig 14 above, in order to produce bio gas in the Zambian city of Andolla, with raw materials coming from waste and waste water facilities. According to Mr Laitinen, the project was embarked upon in order to learn how to transfer already matured Finnish landfill technology to Africa. The company took some of the following steps below to proceed with the project:

1. Local partner: They seek for local partner that will be committed to the success of the project, whose involvement with the project can lead to further cooperation of starting similar projects in other regions of Zambia. The local partner will handle all the local contacts and bureaucracy.

2. Raw material source

The importance of a constant supply of raw material cannot be overemphasised due to the high finacial cost that characterize renewable energy projects. The city of Andolla in Zambia, where the projects are planned to be located has two waste water treatment plants and some mining companies. The project design prefers the sludge from the waste water companies.

3. Support from Government and local companies

Getting the support of host government and local companies that will be involved in the supply chain of producing the biogas is important. It will promote a win-win situation. Doranova provides the bio-gas and the economy starts developing due to creation of jobs.

4. Clients

The energy, heat and gas generated from the bio gas plant will be used to power the plant and greenhouses, while adequate arrangement will be make with the utility company to handle the energy sales to the community.

5. Funding

As the project is being designed, the source of funding is being carried on. It is a long process that involves a lot of paper work.

Some of the challenges identified in the Zambia project were poor maintenance culture in Africa, selling of electricity that will be generated to the local consumers, training the community about adequate sorting of waste from source, gaining the loyalty of the local personnel on site and government regulation policies.

4.6.1 Doranova's perspective on Lagos

From Mr Latinen's point of view, a bio gas plant project will be feasible in a city like Lagos with large population, if the maintenance, operation and energy sales can be handled by local personnel and relevant government agencies. With the existence of more than one landfill sites in Lagos, the project can start on a landfill where more than one gas plant can be built on a single landfill to generate landfill gas, using the same investment, same engines, same power grid connections and the same personnel. The plant can even be upgraded to a bio-refinery plant that will be producing bio-ethanol for vehicles.

5 RESULTS

The objectives of this research paper were to analyze three bio-energy sources within Lagos metropolis, analyze the present waste management methods of Lagos and identify means of turning the challenges into opportunities that could be utilized. This led to the identification of some research questions like: what is the present stage of waste management in Lagos, what are the renewable energy solutions that can be generated by efficient waste management practice, who are the energy stakeholders in Lagos and what are the untapped potentials that could be utilized by proper engineering of Lagos landfills and unused saw dust produced from the Okobaba wood processing factories?

Most of the targets were achieved. Bio-energy as a potential renewable energy was identified from the study, especially if research and investment efforts can be directed towards the development of Lagos landfills and conversion of the bio-waste component of the municipal solid waste.

Also the research could contribute to the understanding of efficient waste management as significant tool towards a sustainable and aesthetic environment, and further development of renewable energy as an alternative source to the combustion of fossil fuel.

The production of briquette from the unused saw dust could be a good alternative to the cooking fuel that an average family uses in Lagos. The author believes that the implementation of this study's result could lead to a positive chain reaction within the society. It can provide information on business opportunities related to waste management and renewable energy production in Lagos.

5.1 Estimation methods for calculating methane emission from landfills

There are two basic methods recommended by the Independent Panel on Climate Change (IPCC 1996).

Default Method

The first one and also the simpler one is the default methodology. It is based on the assumption that all potential methane is released in the same year the waste was deposited, which is not really the case.
This method is mainly used for regions where more detailed data on waste is not available. 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)=

(MSWT x MSWF x MCF x DOC x DOCF x F x 16/12 - R) x (1-OX)
where:
MSWT = total MSW generated (Gg/yr) and can be calculated by multiplying the population with annual MSW generation

MSWF = 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 5 m 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

DOCF = 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

F = fraction of CH4 in landfill gas (default is 0.5)

R = recovered CH4 (Gg/yr)

OX = oxidation factor (fraction - default is 0)

First Order method

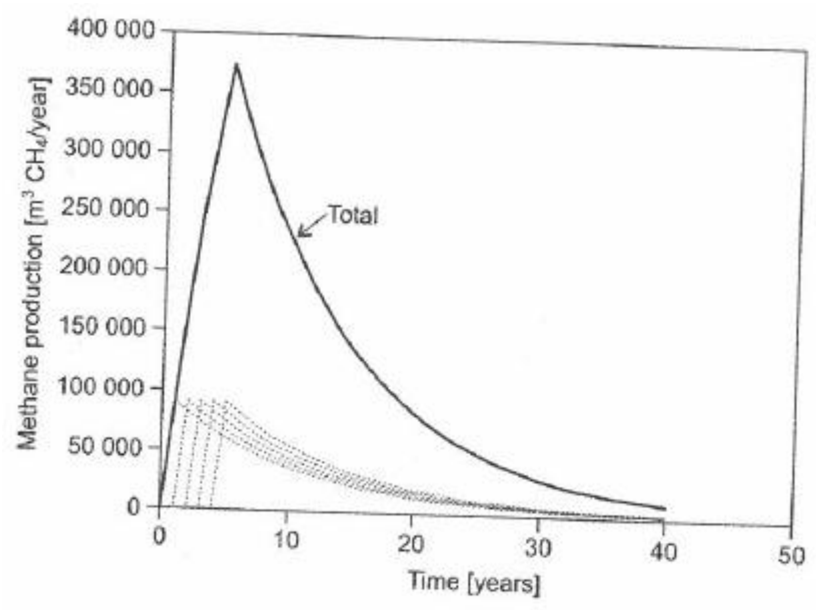

Fig 14 . Predicted total methane production from a landfill that has received over 10,000 t/year waste. (Willumsen & Barlaz 2012, 841, Adapted by Author)

Methane production from landfills is typically modeled using the first order equation below. This method is appropriate for a landfill that is managed and has enough data for experimental purposes.

$G= W_{aL}ok_e^{-kt}$

Where

G= CH_4 production rate from a single year's refuse (m^3 CH_4/ year)

W_a= annual waste acceptance rate (t/year);

L_o= ultimate methane yield (m^3 CH_4 /t)

k= decay rate (per year)

t= years since the landfill started receiving waste.

5.2 Predicting methane emissions for Olusosun landfill

Using the first order decay model which better represents the emissions of methane from landfills**,** the results are shown in Figure 15 below, using the following assumptions:

_ Lo – Methane generation potential (same as MCF*DOC*DOCF*16/12 in the default method) and here assumed to be about 150m3/Mg.

_ K- methane generation constant for lack of data is assumed to be -0.05 (the default suggested by IPCC)

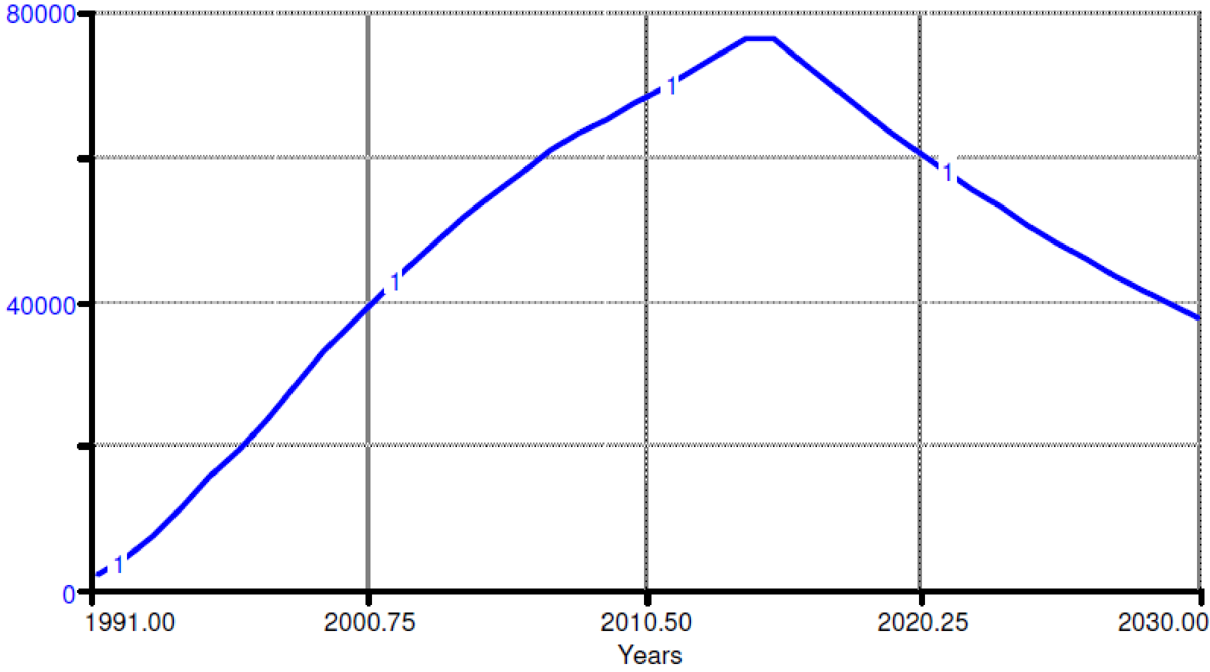

Fig 15 Methane emissions from Olushosun landfill (Akinwale 2004, Adapted by Author)

The graph shows methane emission from Olusosun reaching its peak of about 76,000 tonnes of methane in 2014 and about 40,000 tonnes in 2030. It shows that Olusosun will still be generating emissions well beyond 2030. A sensitivity analysis varying k and Lo by ±15% shows that this varies from a low of 47,000 tonnes to a high of 78,000 tonnes CH_4. (Aboyade 2004) (Adapted by Author) .

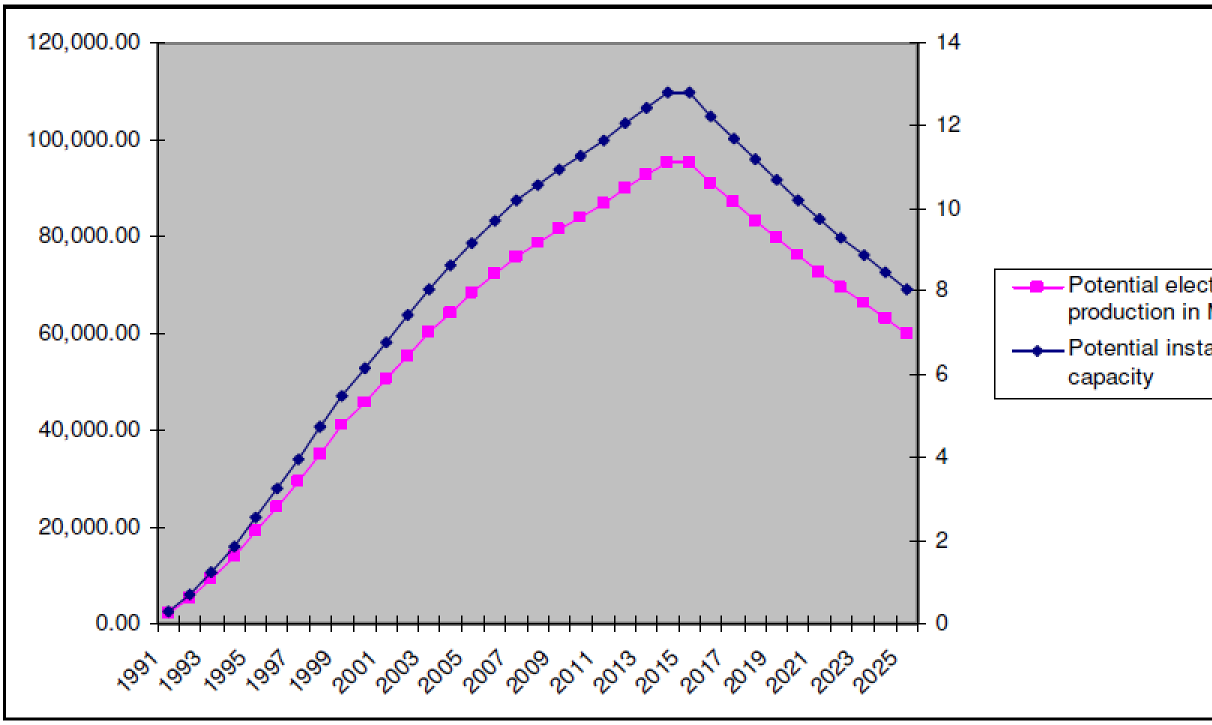

Fig 16 Potential energy generation of Olushosun landfill (Aboyade 2004, Adapted by Author)

Figure 16 above depicts the energy potential of methane that can be generated from Olushosun landfill with 60 % collection efficiency. It is also based on energy generation potential of 33.8MJ/m^3 of methane .

The research is directed towards sustainable development within the context of waste management, climate change and socio-economic benefits. It shared the governing principle of Intergovernmental panel on climate change the main function of which is " ... *to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they may need to deal objectively with scientific, technical and socio-economic factors relevant to the application of particular policies*." (History of IPCC 2014).

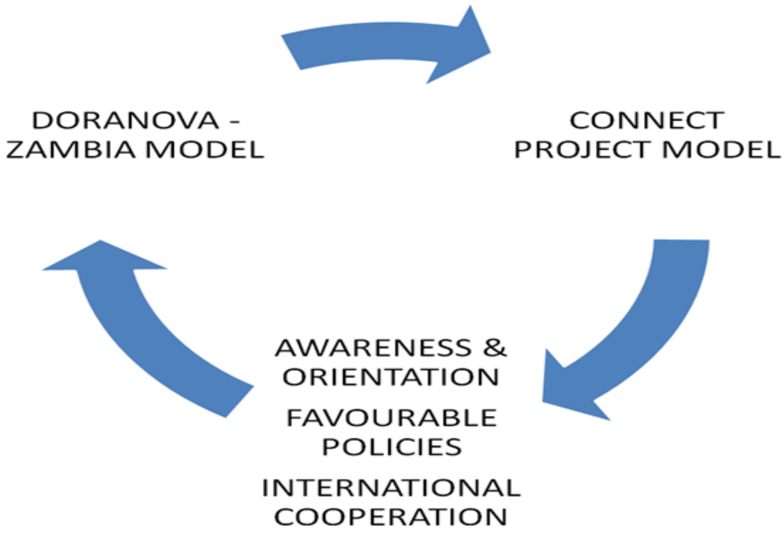

Fig 17 Cyclic model (Author's construct)

On a personal note, I will propose a combination of related models in order to achieve the best result of effective waste management in Lagos and to positively affect the society. Public orientation , most especially towards separation of waste from source, should be encouraged. Lagos state government should continuously formulate and implement environmental friendly policies that will attract the cooperation of foreign technical partners and investors.

The mere availability of renewable energy sources does not mean that they are readily available for exploitation. A lot of factors need to be takent into consideration, such as maturity and cost of technology, ease of mobilizing investment, quality of the renewable fuel source, conversion cost, quantity of the renewable energy resources and demand.

Also, it was not possible to get direct interviews with the employees of Lagos State Waste Management Authority. Calls made to the telephone lines on their website were not picked, sms messages and emails sent were not replied. A research method that would include landfill physical inspection and direct interview with the energy stakeholders would have gone a long way to further establish the results of this research .

More detailed research is needed to further provide specific data about the utilization of Lagos waste and biomass potentials into energy and other products. Also, further investigation into a business model that is applicable to Lagos business environment and plant site selection will be a necessity before any implementation should start.

6 CONCLUSION

The large quantity of waste and other bio energy resources generated daily in Lagos metropolis can be an indicator that will necessitate the establishment of similar schemes as the CONNECT project. The proposed scheme for Lagos waste utilization can be similar in operation, where it will be in the middle and act as intermediary between Lagos Government and interested renewable energy companies. Also a combination of such scheme with a model similar to the Doranova Zambian model and effective public englightment will yield positive results towards creating a sustainable waste management for Lagos city.

As stated in section 4.4.3, that shows the willingness of Lagos Waste Management Authority to take up the challenge of extending its services to other African countries, the future involvement of foreign and private partners is inevitable to the development of technology needed for effective waste management practice..

If the challenges stated in previous chapters can be worked on, this can turn into an economic potential, especially if the Zambian city model with adequate research and investment can be replicated, and the landfills of Lagos are converted to bio gas or bio refinery plant sites. Since most MSW is generally dumped on landfills after collection, these can be directly combusted in waste-to-energy facilities, or sorted for recyclable materials to be recycled and re-used. With the present orientation and importance attached to waste by most of Lagos residents, the Lagos State Ministry of Energy and Mineral Resources is ready to work closely with Lagos Waste Management Authority and private sector to initiate projects for efficient use of Lagos waste and for the generation of energy from landfills, most especially the two largest ones from Olushosun and Abule Egba. This will lead to the most desired energy mix to power the industries and further contribute towards a sustainable method of managing Lagos waste.

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APPENDICES

List of Tables

Table 1 Biomass resources and estimated quantities in Nigeria for year 2004

Table 2 Lagos metropolitan area land use structure

Table 3 Method of Waste disposal among Lagos residents before and after Year 2005

Table 4 Quantity of waste utilized and landfilled by PHJ

Table 5 MSW generated in Ghana Main Cities

Table 6 Classification of general waste in Lagos metropolis

Table 7 Estimated power generation potential from MSW within Lagos Metropolis

Table 8 Heating values of some wood based solid fuels and coal

Table 9 Showing Lagos State agencies and their roles

List of Figures

Figure 1 Shares of Energy Consumption by source in Nigeria

Figure 2 Nigeria Energy Supply for year 2005

Figure 3 Map of Nigeria

Figure 4 Aerial view of Kujala Waste Center

Figure 5 Network of gas collection pipes at Kujala Waste Center

Figure 6 Composition of waste generated in Ghana

Figure 7 Waste Characterization in Lagos Metropolis

Figure 8 Aerial Map of Okobaba Community indicated by the yellow polygon

Figure 9 Screw Press Briquette Production Machine

Figure 10 Piston Press Biquette Production Machine

Figure 11 Layout plan of Olushosun landfill

Figure 12 Schematic Diagram of CONNECT project model

Figure 13 Doranova Waste to Energy Cycle

Figure 14 Predicted total methane production from a landfill that has received over 10,000 t/year waste

Figure 15 Methane emissions from Olushosun landfill

Figure 16 Potential energy generation of Olushosun landfill

Figure 17 Cyclic model

List of Abbreviations

FIT - Feed In Tarrifs

IPCC-Intergovernmental panel on climate change

LFG - Landfill gas

LMOP -Landfill Methane Outreach Programme

MSW-Municipal Solid Waste

TLS - Transfer Loading Station

TPD - Tonnes per day

WMW- Waste management world

WTE - Waste to energy

Appendix 1 Interview questions Jarno Laitinen of Dora Nova Oy.

What is the current share of renewable energy in your company's turn over?

What are the emerging technologies in renewable energy sector and how have you been able to keep up with them?

How has your experience in the Baltic States prepared you to launch into other parts of the world?

Have you transferred your business and technology expertise outside the Baltic region?

If yes, how has the experience been?

If No, what are the reasons for not taking the steps?

Can you tell us about your company's pilot project in Zambia?

Are there plans for other parts of Africa?

What are your opinions concerning the brief report on Lagos business opportunities that we sent to you?

With the readiness of Lagos state to provide necessary support in terms of land space, tax break and other incentives, do you consider it as a feasible project to embark on?

How do you think we can continue from this stage, what are the other questions that you need about Lagos?

Appendix 2 Interview questions for Tosin Ajaga of Nicom group, Lagos.

Theme 1: General Questions

What are the main activities/responsibilities that your company does?

Can you briefly define your roles in this company?

What are the goals and visions of this company?

Can you please tell us about some of the challenges your company has been facing recently?

How has the company cope with the challenges over the years?

How do you view the importance of innovation and development to the waste management industry?

- Theme 2: Importance of company operation to sustainable urban development and better environment

Are you familiar with emerging new technologies in waste management?

What are your opinions about them?

- Theme 3: Opinions on how knowledge and technology transfer can contribute to the growth of waste management in Lagos.

What are your opinions on how technology transfer can contribute to the waste management sector of Lagos state?

Appendix 3 Statistical analysis of refuse dumped by Lagos residents in January 2013

STATISTICS OF REFUSE DEPOSITED (CUBIC METERS) FOR THE MONTH OF JANUARY 2013

S/N	LANDFILL SITES	TRUCK TRIPS & CUBIC METERS OF REFUSE DEPOSITED BY VARIOUS AGENCIES								TOTAL		REMARKS (%)
		LAWMA		P.S.P		M.O.E.		L.G				
		TRUCKS TRIPS	PUB. & MARKET	TRUCKS TRIPS	FRANCHISE	TRUCKS TRIPS	PUB.	TRUCKS TRIPS	PUB.	TRUCKS TRIPS	METRIC TONS OF REFUSE	
1	OLUSOSUN	2,368	50,939.71	7,397	143,817.05	91	1,297.30	45	467.78	9,901	196,521.84	57
2	SOLOUS II	497	12,013.72	1,838	37,604.99			14	174.64	2,349	49,793.35	15
3	SOLOUS III	429	8,939.29	2,239	47,785.86	8	158.00	17	137.21	2,693	57,020.36	17
4	EWUELEPE	54	1,426.20	1,208	23,018.71					1,262	24,444.91	7
5	EPE	42	764.03	769	13,467.78					811	14,231.81	4
	TOTAL	3,390	74,082.95	13,451	265,694.39	99	1,455.30	76	779.63	17,016	342,012.27