THE POTENTIAL FOR ELECTRICITY GENERATION FROM MUNICIPAL SOLID WASTE IN LAGOS STATE, NIGERIA

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ABSTRACT

Nigeria is rich in fossil fuel resources, but these are mainly exported. The local infrastructure for electricity generation is insufficient, as it is only available in urban areas, and suffers from frequent interruption. Only a small percentage of the population benefits from grid electricity, with the remainder using diesel generators, or has no access to electrical power.

In recent years the population of Nigerian cities has rapidly expanded, outstripping the infrastructure, including the waste disposal sector. Recently waste management plans have been put in place for Lagos, with improved facilities for waste collection, landfill gas recovery, recycling and composting included in the waste management strategy. However, there has been no inclusion of direct energy recovery from wastes prior to landfill. A facility providing electricity generation from MSW (municipal solid waste) combustion offers the possibility of reliable electricity generation, reduced GHG (greenhouse gas) emissions, reduced waste volumes to landfill and extended landfill site lifetime.

In this paper the typical waste distribution for Lagos is examined, its energy content evaluated, and the potential of using this waste for electricity generation examined and assessed. A proportion of the waste was considered to be available for energy recovery – as part of the waste management options, so that recycling and composting would still have their role. The economic viability of a 50 MWe EfW (Energy from Waste) combustion facility was first assessed using the Eclipse process simulator to calculate the Breakeven Electricity Selling Price (BESP), where the standard landfill tipping fee was assumed to be given to the EfW plant as a processing charge. The EfW plant BESP was found to be very competitive with typical coal-fired power plants. The BESP for the 50MWe EfW plant (Base Case) was found to be 9.57 £/MWh, with a payback period of 15 years, when the current tipping fee of £50/tonne of waste was charged for disposal (gate fee) at the EfW plant. This compares very favourably with the BESP for a typical 600 MW supercritical pulverized coal-fired power plant, which would be 35.7 £/MWh in the USA and the current electricity cost of 39.5 £/MWh in Nigeria.

The sensitivity of BESP to plant capital costs, load factor and tipping fees was also calculated and analysed.

Keywords: municipal solid waste, energy recovery, energy from waste, emissions reduction.

NOMENCLATURE

Abbreviation

AD	Anaerobic Digestion
BESP	Break-even Electricity Selling Price
CC	Capital Costs
CHP	Combined Heat and Power
EfW	Energy from Waste
EPC	Equipment Costs
IGCC	Integrated Gasification Combined Cycle
LAWMA	Lagos Waste Management Authority
MBT	Mechanical Biological Treatment
MSW	Municipal Solid Waste
NEPA	National Electric Power Authority
NERC	Nigerian Electricity Regulatory Commission
PHCN	Power Holding Company of Nigeria
RDF	Refuse Derived Fuel

Symbols

MWe	MegaWatts of electricity
toe	tonnes of oil equivalent
tpa	tonnes per annum

Subscript

e	electricity

1. INTRODUCTION

1.1 Economy of Nigeria

Nigeria has aspirations of being a leading African economy. Although Nigeria has extensive fossil fuel resources (see Table 1), which support its GDP position of 32nd in the world, they have been of little benefit to the country's population, since the GDP/capita puts them at 175th globally.

Energy consumption is often taken as an indicator of the wealth of a nation, or of its population. For example, the electricity consumption per capita in Nigeria is 106 kWh, which is far behind South Africa (4,921 kWh), Libya (3,282kWh), Iraq (1,378kWh), Gabon (900 kWh), Ghana (284 kWh), Cameroon) (176 kWh) and Kenya (125 kWh) [1], which implies that Nigerians are not enjoying the fruits of their exports.

Nigeria struggles to provide the infrastructure necessary for a modern economy from its own resources and has been attempting to attract private investment instead.

1.2 Energy Scenario in Nigeria

Oil is the major source of income for the country and accounts for over 95% of its foreign exchange earnings[2].

Nigerian oil reserves are the tenth largest in the world and were estimated to be over 37 billion barrels [2] [3] in 2011 . Table 1 shows the major energy resources in Nigeria.

Table 1: **Nigeria's Current Energy Resources [2]**

Energy Type	Resource Estimate
Crude oil	Over 37 billion barrels
Natural Gas	Over 183 trillion ft^3
Hydro Power	Over 20,000 MW
Coal	Over 2.75 billion tonnes
Solar Radiation	3.5 – 7.0kWh/m^2/day
Wind Energy	2.0 – 4.0 m/s (speed)
Nuclear	Not yet quantified
Biomass	Over 144 million tonnes / year
Wave and Tidal	Over 150,000 TJ/yr (16.6 x 10^6 toe/year)

1.3 Electricity Supply in Nigeria

Most electricity in Nigeria is generated at central power stations using fossil fuel or hydro [4], Table 2 illustrates the breakdown of generating plants in Nigeria.

Successive governments have placed secure, reliable electricity generation as a main priority for both domestic and industrial growth, but all have failed to deliver. In 2008 about 21.1 TWh of electricity were generated [5], which implies around 4.4 GW power operating at 60%. In 2009 about 20.3 TWh [2] were generated, making Nigeria the 70th largest generator in the world. Maximum capacity is around 5.6 GW, but only 3.6 GW (check figs, refs) is available regularly, due mainly to the age of the power plants and inadequate maintenance.

Grid supply is frequently intermittent too, so that the population has come to rely on, often very inefficient, petrol and diesel generators and Nigeria has been named the "Generator Republic". The estimated total private generation of electricity is about 2.4 GW, making Nigeria the largest purchaser of private electricity generating equipment in the world [6]. It is estimated that 60 million Nigerians own private power generating sets for electricity production, spending a staggering NGN1.56 trillion ($13.35bn) to fuel them annually [1].

Table 2: **Generating plants in Nigeria [7]**

Site	Type	Installed capacity [MW]	Capacity Available	Number of units
Afam	Thermal (Gas)	700	488	18
Delta	Thermal	812	540	20
Egbin	Thermal (Gas)	1320	1100	6
Ijora	Thermal (Gas)	66.7	40	3
Sapele	Thermal (Gas)	1020	790	10
Ugheli	Thermal (Gas)	832	618	
Jebba	Hydro	540	450	6
Kaniji	Hydro	760	560	12
Shiroro	Hydro	600	600	6
Orji rivers	Thermal (coal)	60	-	4

In March 2005, a bill was passed for the reform of the energy sector, this led to the creation of the Power Holding Company of Nigeria (PHCN) which took over the duties of national electric power authority (NEPA) who had the monopolistic control of distribution and supply of electricity in Nigeria [8]. The main mandates set for the new organisation was the development of competitive electricity market and structural change to attract investments for the private sector. As of December 2005, the PHCN operated and maintained power-generating stations with a total installed capacity of about 3.96 GW [8].

Table3: Electricity demand projection (GW) scenarios for Nigeria assuming different growth rates [9]

	2005	2010	2015	2020	2025	2030
1	5.7	15.7	28.3	50.8	77.4	119.2
2	5.7	15.9	30.2	58.2	107.2	192.0
3	5.7	16.0	31.2	70.8	137.4	250.0
4	5.7	33.2	64.2	107.6	172.9	297.9

Scenarios: 1= Reference (7%); 2 = High growth (10%); 3 = optimistic 1 (11.5%) 4 = Optimistic 2 (13%)

The energy demand for 2010 was estimated to be over 15GW and projected to be over 28GW by 2015 with a population growth rate of 7% as illustrated in table 3. How-ever, this is unlikely to be supplied under current initiatives.

The electricity price per kWh in Nigeria is currently 10 NGN (0.0395 GBP, or £39.5/MWh) [10] as was proposed in the Tariff Development and Rates Approval - Approved Revenue Requirement [11].

1.4 Waste Management in Nigeria

Until 1977 waste management was almost unknown in

Until 1977 waste management was almost unknown in Lagos, but being voted world's 'dirtiest' capital, when they hosted FESTAC, was a wake up call [12] [13]. Since that time waste management plans have been put in place and recent refinements have included recycling (ref), landfill gas recovery (ref) and composting [14]. However, as yet there has been no attempt to employ energy recovery from waste (EfW) as a method for reducing waste tonnage, generating electricity and reducing emissions.

1.5 Energy from Waste Plants

Modern EfW plants in the USA generate 600 kWh electrical energy from each tonne of waste, thus avoiding mining ¼ tonne of high quality coal or importing one barrel of oil [15]. It also reduces the effect of carbon dioxide and methane release from landfill sites, since even in well-regulated sanitary sites, up to 25% of these gases are released into the atmosphere[15].

This EfW plant could provide a reliable, stable electricity source as well as reducing the amount of waste going to landfill, lowering GHG (greenhouse gas) emissions and conserving fossil fuel resources.

The incineration of waste has the great advantage, that although it does not completely eliminate waste from being deposited at landfill, it reduces its weight and volume. The reduction of MSW has been estimated to be approximately 75% by weight and 90% by volume [16].

1.6 Scope of this paper

Waste arisings in the vicinity of Lagos are assessed in this paper. Waste tonnages and their constituent components are quantified and their potential energy contents calculated, taking into account their calorific values and moisture (and inert material) contents. An EfW plant is proposed at a scale which could operate at a high load factor, but would only use a proportion of the waste so that other aspects of a waste management plan, such as recycling or composting, could still be implemented. The economics of the proposed EfW plant are then assessed.

2. ESTIMATION OF WASTE QUANTITIES, DISTRIBUTION, ENERGY CONTENT AND ENERGY AVAILABLE FOR CONVERSION

2.1 MSW in various cities

The distribution of wastes within the MSW for any city will depend on many factors, but principally there is a marked difference between the MSW of cities in low income countries from that of high income countries [17].

From table 4 it can be seen that the composition of waste in Nigeria is in a common trend compared to other low-income countries as the major component is organic waste (putrescible).

Table 4: **Waste composition of selected cities [17].**

	High income countries		Low income countries			
Waste Material	Brooklyn New York	London England	Medellin Colombia	Lagos Nigeria	Jakarta Indonesia	K Pak
Paper	35	37	22	16.34	2	<
Glass	9	8	2	2.92	<1	<
Metals	13	8	1	2.61	4	<
Plastics	10	2	5	6.41	3	-
Leather, rubber	-	-	-	-	-	<
Textiles	4	2	4	6.72	1	1
Wood, bone, straw	4	-	-	-	4	1
Putrescible	22	28	56	54.72	82	5
Miscell-aneous inert	4	15	10	10.28	3	4
Total	100	100	100	100	100	1

2.2 Waste Data for Lagos

It is difficult to know exact data for waste generation in any country and Nigeria is no exception.

According to Ogwuleka [18], Lagos state produces approximately 255,600 tonnes of solid waste every month (0.63 kg/capita/day) which is primarily made up of household, business and commercial waste (collectively classified as municipal solid waste (MSW). In general these wastes are disposed of by landfilling, with minimal efforts made for source separation [19]. Lagos State government is encouraging private investment in all of the waste management sectors, including electricity, since there are about 9,000 tonnes of waste produced there each day [20]. The Managing Director of the Lagos State Waste Management Authority (LAWMA) has estimated that there are 10,000 tonnes of waste produced per day [21].

Interest in the composting [14], landfill gas use [6] and the recycling [22] sectors have made some headway recently, but electricity generation from waste combustion has not yet been developed.

Table 5**: MSW waste composition in Lagos state**

Components	Average %	Average MSW (Tonnes / Year)	Average MSW (Tonnes / Day)
putrescible	54.72	1,540,120	4,220
Plastic	6.41	180,412	494
Paper	16.34	459,897	1260
Textile	6.72	189,137	518
Metal	2.61	73,460	201
Glass	2.92	82,185	225
Nylon	8.88	249,932	685
Grit	1.4	39,404	108
TOTAL	100	2,814,546	7,711

MSW can be collected from different sectors which includes commercial, industrial and domestic. MSW comprises of different types of waste and in Lagos these include putrescible, vegetable, plastic, paper, textile, metal, glass, nylon and garden grit. This composition will vary with time and the changes in the population's various needs. Even the composition data from the LAWMA has changed over a few years, as shown in Table 5.

From table 4 it can be seen that the composition of waste is different depending on the country, and its level of development. It can be seen that the putrescible component is considerably more important in low income countries when compared to New York and London in table 4.

In this section the following collected data are shown:

- daily/annual MSW generation in Lagos state;
- the composition of waste according to the various sectors i.e. commercial, industrial and domestic;
- the moisture content of the various wastes.

Table 6: Summary of the annual MSW waste collected (Tonnes) for 2009 in the different sectors in Lagos state [2].

MONTHS	COMMERCIAL	INDUSTRIAL	DOMESTIC
January	5,560	14,246	64,461
February	23,538	45,021	197,004
March	33,759	43,303	180,921
April	38,964	46,688	188,672
May	29,440	38,616	152,000
June	12,376	14,845	177,614
July	26,246	34,107	169,206
August	30,934	35,873	195,002
September	45,237	38,435	165,166
October	35,517	33,092	176,049
November	45,745	40,900	160,982
December	45,963	43,250	185,814
Total	373,279	428,376	2,012,891

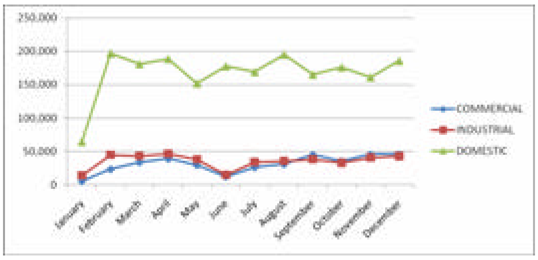

Figure 1: annual MSW waste collected (Tonnes) for 2009 in the different sectors in Lagos state

Table 7: Percentage composition of waste in Lagos Metropolis categorized in the different sectors [25].

MSW Component	Commercial	Industrial	Domestic
Putrescible	66	30	68.16
Plastic	1.77	14	3.46
Paper	22.57	14	12.46
Textile	-	20	0.18
Metal	1.77	4	2.08
Glass	3.98	2	1.78
Nylon	3.92	15	7.68
Garden waste/ Grit	-	-	4.20
TOTAL	100	100	100

Table 8: Percentage change in waste components in recent years

Components	Average % 2008	Average % 2010 [23]	Average % [24]
Putrescible (& vegetable)	54.72	53	60
Plastic	6.41	15	12
Paper	16.34	10	10
Textile	6.72	4	2
Metal	2.61	5	2
Glass	2.92	5	3
Nylon	8.88	n/a	n/a
Grit (Fines)	1.4	8	11
TOTAL	100	100	100

2.3 Estimation of the Energy Content of the Waste for the Proposed EfW Plant in Lagos

In order to estimate the energy content of the waste, the tonnage of 'as received' waste must be known, as well as its moisture content. From this the amount of dry waste can be calculated, and knowing the energy content of each waste type, the energy content of the waste can be obtained. For example, we can calculate the energy content of the putrescible waste as follows:

Table 9: Tonnage of 'as received' waste type per sector per month

Month	Commercial	Industrial	Domestic
January	5,560	14,246	64,461
February	23,538	45,021	197,004
March	33,759	43,303	180,921
April	38,964	46,688	188,672
May	29,440	38,616	152,000
June	12,376	14,845	177,614
July	26,246	34,107	169,206
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Total	373,279	428,376	2,012,891

Table 10: Percentage of waste type per sector

MSW Component	Commercial	Industrial	Domestic
Putrescible	66	30	68.16
Plastic	1.77	14	3.46
Paper	22.57	14	12.46
Textile	-	20	0.18
Metal	1.77	4	2.08
Glass	3.98	2	1.78
Nylon	3.92	15	7.68
Garden waste/ Grit	-	-	4.20
TOTAL	100	100	100

To get the amount of 'as received' putrescible waste/sector/month, the "as received" tonnage in Table 9 is multiplied by the putrescible percentage in Table 10, as shown in Table 11.

Table 11: Total Amount of "as received" putrescible waste per month in tonnes

Months	Commercial	Industrial	Domestic
January	3,670	4,274	43,937
February	15,535	13,506	134,278
March	22,281	12,991	123,316
April	25,716	14,006	128,599
May	19,430	11,585	103,603
June	8,168	4,454	121,062
July	17,322	10,232	115,331
August	20,416	10,762	132,913
September	29,856	11,531	112,577
October	23,441	9,928	119,995
November	30,192	12,270	109,725
December	30,336	12,975	126,651
Total	246,364	128,513	1,371,986

Table 12: Moisture Content of Waste type

MSW Component	Moisture	Dry Matter
Putrescible	70	30
Plastic	2	98
Paper	6	94
Textile	10	90
Metal	3	97
Glass	2	98
Nylon	2	98
Garden waste/ Grit	60	40

Similarly, to get the dry tonnage of putrescible waste/sector/month, multiply the "as received" tonnage in Table 11 by the dry percentage in Table 12, as shown in Table 13.

Table 13: Total Amount of "dry" putrescible waste per month in tonnes

Month	Commercial	Industrial	Domestic
January	1,101	1,282	13,181
February	4,661	4,052	40,283
March	6,684	3,897	36,995
April	7,715	4,202	38,580
May	5,829	3,475	31,081
June	2,450	1,336	36,319
July	5,197	3,070	34,599
August	6,125	3,229	39,874
September	8,957	3,459	33,773
October	7,032	2,978	35,998
November	9,058	3,681	32,918
December	9,101	3,893	37,995
Total	73,909	38,554	411,596

Table 14: Calorific Value for the Dry Waste Components [26]

MSW Component	Calorific Value (GJ/tonne)
Putrescible	18

Plastic	40
Paper	17
Textile	32
Metal	0
Glass	0
Nylon	18
Garden waste/ Grit	4.8

Then, by multiplying the values in Table 13 by 18 GJ/tonne (Calorific value of dry putrescible waste in Table 14), the energy available in the putrescible waste/sector/month is obtained, as shown in Table 15.

Table 15: Energy Content of putrescible waste per month in GJ

Months	Commercial	Industrial	Domestic
January	19,816	23,079	237,258
February	83,889	72,934	725,101
March	120,317	70,151	665,905
April	138,868	75,635	694,434
May	104,924	62,558	559,457
June	44,108	24,049	653,733
July	93,541	55,253	622,787
August	110,249	58,113	717,732
September	161,225	62,265	607,917
October	126,583	53,609	647,972
November	163,035	66,258	592,517
December	163,812	70,065	683,914
Total	1,330,366	693,968	7,408,727

The same procedure is followed for each waste type to get the energy content of all the waste/sector/month, which are shown in table 16.

Table 16: Energy Content of ALL wastes per month in GJ

Months	Commercial	Industrial	Domestic	Total Energy
January	47,571	252,884	573,782	874,237
February	201,391	799,177	1,753,576	2,754,144
March	288,842	768,680	1,610,418	2,667,940
April	333,377	828,768	1,679,411	2,841,556
May	251,889	685,480	1,352,985	2,290,355
June	105,889	263,517	1,580,981	1,950,387
July	224,561	605,440	1,506,142	2,336,143
August	264,672	636,780	1,735,756	2,637,207
September	387,048	682,267	1,470,181	2,539,496
October	303,884	587,423	1,567,049	2,458,355
November	391,395	726,024	1,432,936	2,550,355
December	393,260	767,739	1,653,969	2,814,969
Total	3,193,780	7,604,187	17,917,185	28,715,153
Monthly	266,148	633,682	1,493,099	2,392,929

Average				

The energy data in table 16 were averaged over each month to get the power, in Megawatts, contained in the wastes. For a large modern MSW facility, the electrical efficiency is assumed to be 28%, and the monthly average power output calculated, as shown in table 17. The waste collected is fairly constant over the year, except when the collection is stopped in December, and an EfW plant, which took in all of Lagos's waste, could operate with a very consistently high load factor, ensuring high efficiency, as shown in table 17.

Table 17: Estimated Power Content of ALL wastes per month, in MW. The load factor would be for a 280 MWe single EfW facility.

	Thermal Power	Electrical Power	Load Factor
January	326.4	91.4	0.33
February	1138.5	318.8	1.14
March	996.1	278.9	1.00
April	1096.3	307.0	1.10
May	855.1	239.4	0.86
June	752.5	210.7	0.75
July	872.2	244.2	0.87
August	984.6	275.7	0.98
September	979.7	274.3	0.98
October	948.4	265.6	0.95
November	983.9	275.5	0.98
December	1051.0	294.3	1.05
Average Load Factor			0.92

2.4 MSW Incineration Efficiency

The Waste Framework Directive (WFD) of 2008 categorises energy recovery from waste above waste disposal methods such as landfilling in the waste management hierarchy pyramid, which has given a boost to the inclusion of energy recovery in many waste management plans.

Energy recovery in MSW incinerators is achieved from steam generated. The overall efficiency of recovery in the system is low due to flue gas in the boiler which is corrosive. In order to avoid hot corrosion or the scenario of ash melting, it is essential to maintain low temperatures in the tube and especially in the super-heaters [27]. The required super-heating pressure and temperature are usually with the parameters of 40 bars and about 380-400°c. These restrictions lead to electricity generation efficiencies (LHV) between 22% - 29% [28].

2.5 Landfill Space

The proposed EfW plant would process 500,000 tonnes of waste per annum and the net electricity generated would be approximately 46 MWe.

This would meet a definite need, since the principal landfill site, Olusosun, increased its processed tonnage from 1,080,000 in 2007 to 1,425,000 tonnes in 2008 and to 1,974,000 tonnes in 2008 [21] under its recent waste management upgrade. While new recycling and composting facilities have been put in place, there would still be a significant increase in landfill space usage.

Table 18: Ranking of Waste Management Activities in terms of GHG mitigation

Scenario	Emissions Offset kg CO_2/tonne waste	Ranking
EfW	12	2
EfW (CHP)	-216	1
MBT & landfill	104	3
MBT, RDF and Landfill	224	5
MBT with AD	210	4
Landfill with gas capture	502	6

Abbreviations: CHP: Combined Heat and Power; MBT: Mechanical Biological Treatment; RDF: Refuse Derived Fuel; AD: Anaerobic Digestion.

Clearly the EfW plant could handle >25% of the non-recycled or non-composted waste, thus extending the lifetime of the available space by more than 30%.

In Europe there are no standard EfW plant sizes; size differs from country to country with the Netherlands preferring larger, centralized 480,000 tonnes per annum (tpa) scales on average whereas Norway, on the other hand, has more examples of the smaller 60,000 tpa size [29].

2.6 Emissions Reduction and Reduction in Fossil Fuel Use

The methodology in the IPCC's guidelines for national greenhouse gases inventories [30], as described by Tsai [18], is used to estimate the GHG emissions reduction and the energy savings through using MSW instead of fossil fuels.

2.7 CO_2 Mitigation

The use of an EfW plant is ranked second only to a EfW plant with heat recovery with regard to GHG mitigation, as shown in the Table below [31]. In Europe such technologies are in widespread use with 67 EfW CHP plants reported in municipal heating schemes in 2005 [32].

Assuming the EfW plant has a net output of 46 MWe and a capacity factor of 92%, then it will generate around 370.7 GWh of electrical energy per year. If we assume that this electricity were replacing that generated by a coal-fired power plant, or small, inefficient private diesel-fired generator, which emitted around 0.65kg CO_2 per kWh of electricity generated, then the use of the MSW EfW plant would result in a mitigation of around 0.24 million tonnes of CO_2 per annum.

[Note: all of the combustible waste, except for the plastic fraction, is biogenic and not fossil in Nigeria.]

3. RESULTS OF ECONOMIC ANALYSIS

The ECLIPSE process simulation package [33] has been used for the techno-economic analysis of a wide range of power plants, such as advanced Integrated gasification Combined Cycle systems [34] or biomass co-combustion systems [35]. In this paper it was used to make a preliminary calculation of the break-even electricity selling price (BESP) of the 50 MWe EfW facility, using the assumptions in Table 19.

Table 19: ECLIPSE Cost Data Overview for 50 MWe (46 MWe net) EfW plant

The tipping fee was assumed to be £50/tonne of waste, which was income for the EfW plant for the

Total Process CC (EPC) (£k, 2011)	110,000.00
Working Capital (EPC, %)	2.00
Capital Fees (EPC, %)	0.40
Contingency (EPC, %)	10.00
Commissioning Cost (EPC, %)	1.00
Total CC (inc. commissioning costs, working capital & fees)	113,740.00
Total CC (inc. contingency)	124,740.00
Specific Investment (£/kWe)	2,472.6
Annual Insurance Costs (%)	1.0
Annual Operating Costs inc. labour & supplies (%)	2.0
Discounted Cash Flow Rate (%)	9.0
Annual Maintenance Costs inc. labour & supplies (%)	2.5
Tipping Fee (£/tonne)	50
Ash Disposal Cost (£/tonne)	50

waste processed there. The same amount was also assumed to be charged for the ash disposed of to landfill from the EfW to landfill – 11% of the waste is assumed to be ash, and 70% of this ash is landfilled, with the remainder being recovered metal. [This is perhaps unnecessary, since the ash can often be used by the landfill operator as a cover material for the landfill or as a low-grade aggregate in construction [36].]

With these assumptions, which will be termed the Base Case, the BESP was found to be 9.57 £/MWh with a payback period of 15 years (as shown in Figure 1, where the gate fee is £50/tonne).

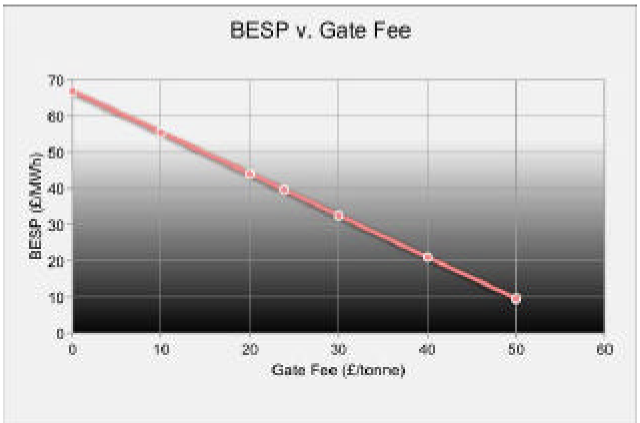

Figure 2: BESP versus Gate Fee for Base Case

4. SENSITIVITY ANALYSIS

While care has been taken to use the most appropriate values for the economic analysis, these are subject to the vagaries of the economic climate. For this reason a sensitivity analysis was carried out in order to assess which factors would influence the BESP most.

4.1 Capital Cost Variation

For the same Gate Fee and Tipping Fee for Ash of £50/tonne, the variation of Specific Investment of 25%, 50% and 100% from the Base Case and their effect on BESP are shown in Figure 3.

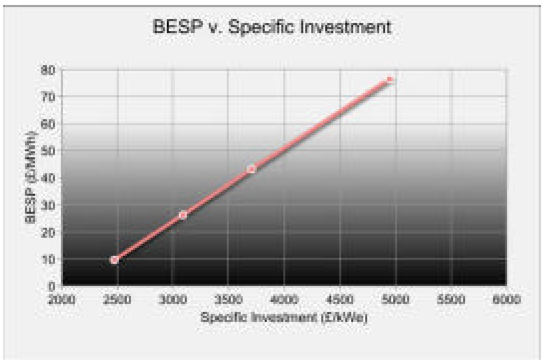

Figure 3: BESP versus Specific Investment

In Figure 4 the variation of BESP with Gate Fee (and Tipping Fee) is shown for the same range of increase in capital costs (+25%, +50% and +100%) with the Base Case.

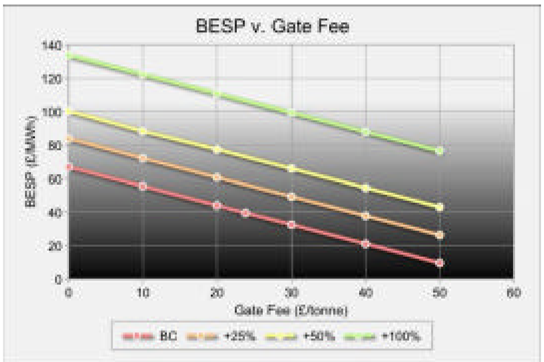

Figure 4: BESP versus Gate Fee for Increasing Capital Costs

It can be seen that, if the capital costs are actually 50% higher than the Base Case, then it would not be possible to generate electricity at the current market price of 39.5 £/MWh in Nigeria. In fact to achieve this electricity price (39.5 £/MWh), and for a Tipping Fee of £50/tonne of waste (for the ash), then the Gate Fee would have to be 25.88, 39.35, 52.87, and 79.75 £/tonne for the Base Case, +25%, +50% and +100% increased capital cost cases respectively.

4.2 Load Factor

The Load factor (LF) can also have a significant impact on the BESP. It has been assumed that the LF would be relatively low in the first three years of operation and then the plant would operate at a fixed LF value. In the Base Case, this was taken as 92% (corresponding to 11 months continuous operation). However, should it not be able to operate at this LF, the BESP will be affected.

Figure 5 shows the impact of Load Factor variation on BESP for the Base Case.

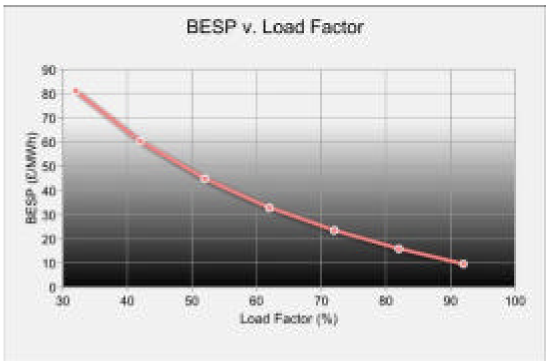

Figure 5: BESP versus Load Factor for Base Case

5. CONCLUSIONS

A method has been shown for assessing the MSW in Lagos for its potential in generating electricity. The type of waste and its quantity was found to be suitable to provide thermal energy which could sustainably generate electricity from an EfW plant without hindering other aspects of waste management in Lagos. The economics of this plant were found to be favourable in comparison with modern coal-fired power plants, for the capital costs assumed, and much better than the widespread use of small-scale generators in terms of economics and environmental impact.

The BESP for the 50MWe EfW plant (Base Case) was found to be 9.57 £/MWh, with a payback period of 15 years, when the current tipping fee of £50/tonne of waste was charged for disposal (gate fee) at the EfW plant. This compares well with the BESP for a typical 600 MW supercritical pulverized coal-fired power plant, which would be 35.7 £/MWh [37] in the USA and the current electricity cost of 39.5 £/MWh in Nigeria. If the electricity from the EfW plant were sold at this price, then a Gate Fee and Tipping Fee (Ash Disposal Cost) of only £23.87/tonne would be necessary to break even. If the Tipping Fee remained at £50/tonne, then the Gate Fee would have to rise to £25.88/tonne to generate electricity at the market price. This would then be an attractive method of waste disposal, since it is half the cost of landfilling, reduces emissions, increases landfill lifetimes and provides a reliable, non-intermittent, indigenous means of electricity generation.

A decrease in Load Factor can have a significant impact on the BESP. However, in this case, the Load Factor could drop as low as 55% and the EfW plant would still be economically viable. This is unlikely to happen as the waste supply is fairly constant throughout the year and the plant has been sized to only rely on about 50% of the 2007 waste at Olusosun landfill site.

In Fig 4, which shows the variation of BESP with Gate Fee for capital cost increases, it can be seen that, if the capital costs are actually 50% higher than the Base Case, then it would not be possible to generate electricity at the current market price of 39.5 £/MWh in Nigeria. In fact to achieve this electricity price (39.5 £/MWh), and for a Tipping Fee of £50/tonne of waste (for the ash), then the Gate Fee would have to be 25.88, 39.35, 52.87, and 79.75 £/tonne for the Base Case, +25%, +50% and +100% increased capital cost cases respectively. Therefore, the plant would still be viable when the capital costs increased by 25%, but not above that.

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