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ECONOMIC SUSTAINABILITY OF UTILIZING SOLID-WASTE GENERATED IN GOMBE-METROPOLIS FOR RENEWABLE ENERGY PRODUCTION

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Abstract

The result of the assessment for the economic sustainability of utilizing solid waste generated in Gombe metropolis for renewable energy production shows that INEX dumpsite has the Power Generation Capacity of 361,963.2 kWh/day at a Capital Cost of

INTRODUCTION

The use of solid waste for energy recovery is a widely practiced technology option in Europe where constraint of land for disposal is acute, when compared to U.S.A. Combustion of waste leads to a reduction of 90% by volume and 75% by weight, thus requiring lesser area of land for disposal. Most of the governments in developed countries are depending on all forms of SWM strategies, including energy generation from the solid waste, to minimize and reduce anticipated future waste management burdens. The Southern European Union countries of (EU) are developing innovative measures to help them in implementing integrated MSW management and to

N259,220,000.00 and needs Operation and Maintenance Cost of N5,580,000.00 per year, and can generate Revenue of N43,203,333.3 per year with a Net Present Value of N4,122,621.3 per year, the Internal Rate of Return will be at 14%, and have a Pay Back Period of 6.8years. While the GOSEPA dumpsite has the Power Generation Capacity of 77,613.8 kWh/day at a Capital Cost of N133,088,000.00 and needs Operation and Maintenance Cost of N2,856,000.00 per year, and can generate Revenue of N22,181,333.3 per year with a Net Present Value of N2,116,623.2 per year, the Internal Rate of Return will be at 14% and have a Pay Back Period of 6.8years. Furthermore, the result of the economic assessment of electricity generation from the two dumpsites through solid waste incineration shows that the Net Present Value is positive at electricity cost of N29.8/kWh, and the cost is comparable with a study by (Amoo et al., 2013) who found out that electrical power generation using incineration plant could provide electricity at a cost of N32.5/kWh in Lagos and Nsukka. The result therefore implies that investment is profitable at N29.8/kWh in Gombe metropolis. The research recommends that INEX cleaners and Gombe State government should establish waste-to-energy plant at the two dumpsites (INEX and GOSEPA) for providing base load renewable electrical power in the State.

Keywords:
Economic Sustainability, Generated in Gombe Metropolis, Renewable Energy Production, Utilizing Solid Waste

reach EU waste management directives, whereas the Central EU countries need models and tools to rationalize their technological choices and management strategies (IEA, 2003). Germany, Netherlands, Belgium, Austria, Sweden and Denmark represent the more advanced countries from an environmental point of view, the benefits derived from a proper Solid waste management in developed nations include greenhouse gases emission prevention, pollutants reduction,

energy saves, resources conservation, new jobs creation, development of green technologies and economic opportunities (Scharfe, 2010

Most of the solid waste generated in developing countries (Africa, Caribbean and Pacific) are from homes (domestic) and the management system comprises of both formal and informal systems (IEA, 2003). For a variety of reasons, poor waste management practices and associated public health implications remain severely problematic in many developing countries a century and a half after the European sanitary revolution, despite increasing globalization (Scharfe, 2010). IEA (2003) pointed out that the best approach to solid waste management (SWM) in developing countries has been an important concern for researchers and policy-makers because in developing countries, data on waste generation and composition are largely unreliable and insufficient (Scharfe, 2010). SWM should not be viewed from a narrow perspective of collection and disposal, but should instead be seen as a part of issues arising out of rapid urbanization.

Evidence suggests that significant progress have been made in many low and middle-income countries over the past few years, particularly those with gross national income (GNI) per capita above USD 2,500 per year. At the same time, median collection coverage is still around 50% in low-income countries and figures are much lower in some countries. It also drops sharply in the more rural areas of many of these countries. It is estimated that at least 2 billion people worldwide who still lack access to solid waste collection are mostly living in developing countries (IEA, 2003). It further reported that in these countries, waste disposal is often in the form of uncontrolled dumpsites with open burning. It is estimated that at least 3 billion people worldwide still lack access to controlled waste disposal facilities.

Sanitary landfill requires much greater initial investment and hence higher operating costs than controlled dumps. Sanitary landfill technologies were introduced in Lagos and Onitsha some decades ago. But presently the landfills are not operational. Open dumping is the most common practice. There is no landfill regulation or standard that provides a basis for compliance and monitoring. Wastes in open dumps are set on fires in order to reduce its volume. Incineration is the high temperature combustion of wastes, incineration and waste to energy (WtE) is not practiced in Nigeria

except in the hospitals where medical wastes are incinerated at a small scale without energy recovery (Scharfe, 2010).

LITERATURE REVIEW

Reliable energy supply is essential in all economies for heating, lighting, industrial equipment, transport, etc. (International Energy Agency, 2014). Renewable energy supplies would reduce the emission of greenhouse gases significantly if it replaced fossil fuels. Since renewable energy supplies are obtained naturally from ongoing flows of energy in our surroundings, it should be sustainable (Twidell & Weir, 2015).

MSW is a renewable form of energy that includes both commercial and residential wastes generated in municipalities. The US Environmental Pollution Agency (USEPA) goes further to classify MSW as a source of clean energy. From a sustainable development perspective, the focus is on reduction of waste, followed by recycling, both of which are advantageous in terms of reducing greenhouse gas emissions. Several analysis done using the USEPA models show that WTE avoids 36 million tons of greenhouse gases yearly (Amoo et al., 2013). WTE is hardly a new or novel idea, what is however new is the confluence of factors that have increased the attractiveness of the WTE. These factors include rising oil prices, urban air pollution, energy supply security, reduction in foreign oil imports, carbon dioxide (CO_2) emissions, and climate change. These considerations are not confined to a single nation or part of the world and thus render the concept of WTE as abundantly and equitably available to humanity. Energy recovery through WTE can be define as a waste treatment process that allows for the generation of energy in the form of electricity or heat from wastes that would have otherwise been disposed of in landfills (Amoo et al., 2013).

Energy from waste is a proven renewable energy source that recovers hidden energy from solid waste (Krizan., Matus., Soos., Kers., Peetsalu., Kers., & Menind., (2011); Baran., Mamis., &Alagoz., (2016). IEA (2003) defined renewable energy as “Energy resources that are naturally replenishing but flow-limited. Municipal solid waste (MSW) is a viable source of energy for electricity generation and minimization of greenhouse gas emissions Rahman., Bin.,& Mohammad., (2015);El-Hanandeh., and El-Zein., (2010).

Psomopoulos., Bourka.,& Themelis., (2009) reported that the US Department of Energy (US DOE) categorizes Waste to Energy as a type of

biomass energy, the term "biomass" means any plant-or animal-derived organic matter available on a renewable basis.

Solid Waste Management System

Solid waste management (SWM) system includes the generation of waste, sorting, storage, collection, transportation, processing and final disposal (IEA, 2003). SWM starts with the sorting and collection of solid wastes and ends with their disposal and/or beneficial use. Waste management systems must remain flexible in light of changing economic, environmental, social and other local conditions (Scharfe, 2010). In most cases, waste management is carried out by a number of processes, many of which are closely interrelated.

Solid Waste Generation

Solid Waste generation rates is the average amount that each person throws away, it varies widely within and between locations. The generation rates depend on income levels, socio-cultural patterns and climatic factors (UNEP, 2009).The rate at which the cities generate municipal solid waste is increasing due to rapid population growth and urbanization; this is more peculiar to cities in developing world. It is important to have adequate information about solid waste generation if a wise decision about future waste management is to be made. Solid waste generation is correlated with the population of an area or city, due to which bigger cities with high population tend to generate more waste than those with low population. The total amount of solid waste generated per person per day in many cities of developing countries has noticeably increased as well. It has almost doubled during last ten years from 0.64 kg to 1.2 kg and is expected to reach 1.42 kg by year 2025 (World Bank, 1999). High income countries generate more waste per person compared to low income countries due to differences in GDP (IEA, 2003). It is worthy to note that even within the same country or region the per capita generation may differ due vibrancy of economic activities, consumption pattern and local climate. In Nigeria Amoo et al., 2013 reported that the waste generation rates ranged from 0.44 to 0.66 kg/capita/day but this varies from city to city and even within cities.

Solid Waste Composition

The rate of waste generation and composition are index of socio-economic development and economic prosperity of a city or region. The municipal solid waste composition is influenced by many factors such as culture, economic development, climate and energy sources (IEA, 2003).The types of waste produced change according to the standard of living in a city. Wastes generated in low and middle-income cities have a large proportion of organic waste, whereas the wastes in high-income cities are more diversified with relatively larger shares of plastics and paper (Scharfe, 2010).

Physical and chemical compositions are of high importance in classification and proper management of Solid waste, based on physical composition IEA, 2003 classified the whole of MSW to include materials (such as vegetables, food, and garden waste), paper and paperboard (including paper, wrapper, cardboard, and packaging paper), plastics (including plastic bags, plastic bottles, and packaging material), glass/ceramics (including glass bottles, broken glass, pottery items and earthen pot), metals (cables, foils, ferrous and nonferrous material), (including textiles), and others including inert and a lot more.

Solid Waste Segregation, Storage and Collection

Efficient collection and transportation are essential parts of the overall solid waste management program of any city (IEA, 2003). Most of the cities in Nigeria are adopting the method of land filling (open dumping) of waste in their respective dumpsites. In most Nigerian states with the exception of the FCT, waste management is only practice in the capital cities. In most cases, the waste materials are collected and transported to open dump areas located some kilometers away from the capital cities and some within the cities. In areas where waste is dump in open space there is very high incidence of disease contraction as well as environmental pollution (Suberu, 2012). IEA (2003) further pointed out that block collection and kerbside collection methods of waste collection are practiced in developed countries. Block collection is the process of conveying of waste by individuals to the waiting vehicles with the help of containers. In kerbside collection, the containers are placed on the footway in advance of the collection time and to be retrieved later.

Solid Waste Transportation

A reliable solid waste collection and transportation system is a cornerstone for good and quality waste management services (IEA, 2003). More so transportation of the collected waste constitutes a key stage in the overall waste management system. In most of the traditional urban centers of developing countries no single mode of collection is effective, economical and efficient due to so many reasons among which include congested and narrow roads as a result of improper planning. Hand cart collection is the best method in narrow and congested roads where the waste can be brought by individuals and transferred to the main transport vehicle. In most of the houses Almajiri's are paid to convey the generated waste to a nearby collection point, some carry it on their head, while some use metal fabricated hand cart. The ultimate destination of the collected and transported waste is the dumpsites (Amoo et al., 2013).

Disposal of Solid Waste

The process of selecting the right waste disposal method is a complex one due to the heterogeneity of the urban waste. Appropriate method of waste disposal can save money and avoids future problems (Suberu, 2012). In Nigeria and perhaps most urban centers of low income countries the predominant methods used for treating municipal solid waste are open dumping, incineration (without energy recovery) and composting. Open dumping of solid waste is the common practiced in most urban centers because it is cheap and requires no planning and the open barrow pits are readily available for disposing the generated MSW. In most urban centers, dumpsites and waste collection points are usually abandon barrow pits and incomplete buildings within the residential quarters and out skirts of the city. Open dumpsites create nuisance to the public by breeding of the flies, rats, mosquitoes and other disease carrying vectors, it is also a source of objectionable odors and causing air pollution. The end products of the solid waste after decomposition are Carbon dioxide and methane (greenhouse gas gases) capable of causing global warming. Open air burning without energy recovery involves burning of solid waste by setting fire on it; the waste is converted in to ashes, metals and unburned combustibles. Open burning may lead to the contamination of the air with dioxins and furan. In Gombe metropolis and almost all of the Nigerian cities there is complete absence of sanitary landfills which entails the method of

disposing of solid waste in engineered design landfills according to the laid down waste management standards (Suberu, 2012).

In major cities of Nigeria and beyond waste scavengers have converted all the dumpsites into mini market where they are trading most of the recovered items and sometimes after exhaustive scavenging they do set fire to the places where they feel has no more any valuable resources to reduce the volume of the waste and allow for further dumping of more waste (Amoo et al., 2013).

Recycling

Recycling involves the recovery of certain materials that can be reprocessed and reused. The materials should be Recycle, compost, or recover materials for use as direct or indirect inputs to new products (UNEP, 2009). Examples of recyclable items include glass (bottles), metals, plastics and paper/cartons. Recyclable items may be collected at the curbside, at drop-off centers or through deposit or refund programs. The recycled items are then brought to a processing facility to be sorted, cleaned, and made into a form that can be used in manufacturing. In most of the Nigerian urban centers recyclable waste are collected by the informal recycling sector prior to and after formal collection by the Agencies saddle with the responsibility of collecting and managing waste. Amount of recyclables collected by informal sector prior to formal collection are generally not accounted for. Suberu, (2012) reported that Informal recycling system is lately receiving its due recognition world-wide for its role in waste management in developing nations.

Incineration/Combustion

In this process, solid waste is directly burned in combustion chambers at high temperature of usually (about 800^{o}C and above) to avoid the deficiencies of conventional incinerators, some modern incinerators utilize higher temperatures of up to 1650^{o}C using supplementary fuel. These reduce waste volume by 97% and convert metal and glass to ash and are the most suitable in treating healthcare wastes (MoUD_GOI, 2000). Heat from combustion can be used as energy source for generation of steam as well as electricity. Incineration has been widely applied in many developed countries, especially those with limited space for landfilling such as Japan and many European countries. Globally, about 130 million tons of waste is

annually combusted in more than 600 plants in 35 countries (MoUD_GOI, 2000). Incineration reduces the mass of waste and can offset fossil-fuel use; in addition, GHG emissions are avoided, except for the small contribution from fossil carbon. Incineration is perhaps the oldest method for recovering the energy stored in MSW (MoUD_GOI, 2000).

Materials and Methods

The Study Area

Location of the Study Area

Gombe city the capital of Gombe State is located in the northeastern part of Nigeria on coordinates 10017'N 11010'E. It has a total area of 52Km^2 (20sq mi) with a population of 377,341 people (2006 census), and the projected population of 534,314.856 people (Adamu et al., 2017). The state has eleven local Governments areas which include Akko, Balanga, Billiri, Dukku, Funakaye, Gombe, Kaltungo, Kwami, Nafada, Shongom and Yamaltu-Deba.Gombe was carved out of the old Bauchi State on 1st October, 1996 by the Military Regime of General Sani Abacha (Misbahu, 2015).

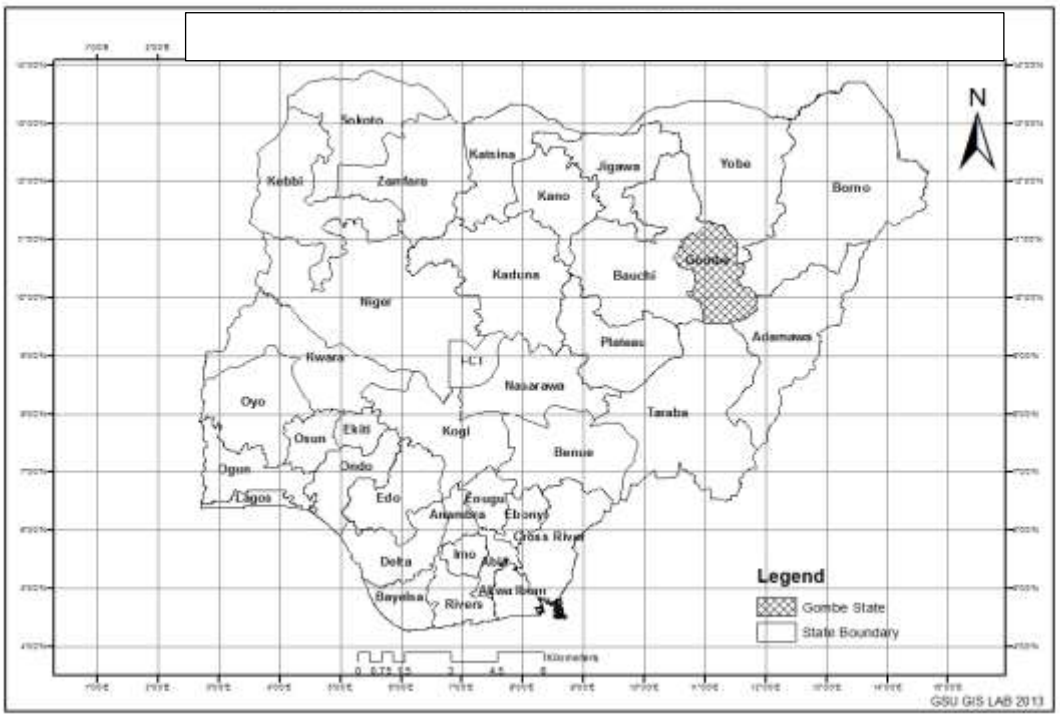

Figure 1: Map of Nigeria showing Gombe State

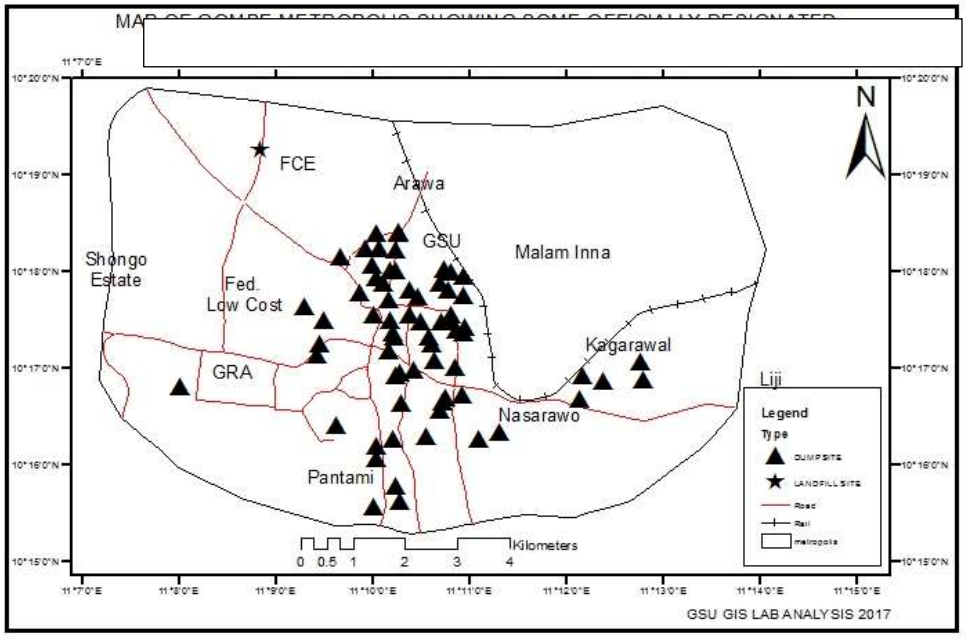

Figure 2: Map of the Approved Waste Collection Centres in Gombe Metropolis

Materials and Method

The main costs associated with waste to energy (WtE) facility are the capital cost and operating cost (US EIA, 2012). In Nigeria, the cost associated with waste to energy facility is not available, therefore capital cost for municipal solid waste power plant have been adopted and modified for this study from the list of updated estimates of power plant capital and operating cost of the United States Energy Information Administration (US EIA, 2012).

RESULTS

Table 1: Electricity and Power Generation Potentials of the Solid Waste from the Two Dumpsites in Gombe metropolis under Study (2019)

Table 1: shows the total potential electricity generation of 439,577 kWh/day from both INEX (361,963.2kWh/day) and GOSEPA (77,613.8kWh/day) by burning 909.13kWh/tonnes of solid waste with

INEX having (509.88kWh/tonnes) and GOSEPA (399.25kWh/tonnes) which translate into generating 18,315.7kW with INEX producing (15,081.8kW) and GOSEPA (3,233.9kW).

Table 1: Electricity and Power Generation Potentials of the Solid Waste from the Two Dumpsites in Gombe metropolis under Study (2019)

S/N	Dumpsites	Potential Electricity Generation (kWh/day)	Potential Electricity Generation (kWh/tonne)	Potential Electricity Generation (kW)
1	INEX	361,963.2	509.88	15,081.8
2	GOSEPA	77,613.8	399.25	3,233.9
Total		439,577	909.13	18,315.7

Source: Laboratory Analysis Adamu, 2019.

Table 2: Average Annual Waste Disposal at the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

Table 2: shows that the initial year when dumping of waste commences at INEX dumpsite was 2009 and as at 2018, 584,978 tonnes of waste have been deposited there with an average annual disposal of 64,997.56 tonnes per year, and the calculated year of the dumpsite closure is year 2034. While GOSEPA dumpsite has 2005 as its year of initial dumping of waste and 225,259 tonnes of waste have been deposited there as at 2018 with an average annual disposal rate of 17,327.62 tonnes per year, and the calculated year of the dumpsite closure is year 2051.

Table 2: Average Annual Waste Disposal at the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

S/N	Dumpsites IYWD	Waste at 2018(t)	Average AWD Tonnes/year	Calculated Year of Dumpsite Closure
1	INEX 2009	584,978	64,997.56	2034
2	GOSEPA 2005	225,259	17,327.62	2051

Source: Laboratory Analysis Adamu, 2019.

Table 3: Economic Parameters of Electricity Generation from Solid Waste at Electricity Cost of N29.8/kWh from the Two Dumpsites (INEX & GOSEPA) in Gombe metropolis under Study (2019)

Table 3: shows that INEX dumpsite has the Power Generation Capacity of 361,963.2 kWh/day at a Capital Cost of N259,220,000.00 and needs Operation and Maintenance Cost of N5,580,000.00 per year, and can generate Revenue of N43,203,333.3 per year with a Net Present Value of N4,122,621.3 per year, the Internal Rate of Return will be at 14% and have a Pay Back Period of 6.8years. While the GOSEPA dumpsite has the Power Generation Capacity of 77,613.8 kWh/day at a Capital Cost of N133,088,000.00 and needs Operation and Maintenance Cost of N2,856,000.00 per year, and can generate Revenue of N22,181,333.3 per year with a Net Present Value of N2,116,623.2 per year, the Internal Rate of Return will be at 14% and have a Pay Back Period of 6.8years.

Table 3: Economic Parameters of Electricity Generation from Solid Waste at Electricity Cost of N29.8/kWh (2019)

S/N	Dumpsite P(kWh/d)	Capital Cost (#)	O&M(N)/Y	R#/Y PBP/Y	NPV(#)	IRR(%)
				#43,203,333.33 6.80	#4,122,621.3	14%
1	INEX 361,963.2	#259,220,000	#5,580,000			
2	GOSEPA 77,613.8	#133,088,000	#2,856,000	#22,181,333.33 6.80	#2,116,623.2	14%

Source: Laboratory Analysis Adamu, 2019.

Discussion of Result

The result in Table 3 shows that INEX dumpsite has the Power Generation Capacity of 361,963.2 kWh/day at a Capital Cost of N259,220,000.00 and needs Operation and Maintenance Cost of N5,580,000.00 per year, and can generate Revenue of N43,203,333.3 per year with a Net Present Value of N4,122,621.3 per year, the Internal Rate of Return will be at 14% and have a Pay Back Period of 6.8years. While the GOSEPA dumpsite has the Power Generation Capacity of 77,613.8 kWh/day at a Capital Cost of N133,088,000.00 and needs Operation and Maintenance Cost of N2,856,000.00 per year, and can generate Revenue of N22,181,333.3 per year with a Net Present Value of N2,116,623.2 per year, the Internal Rate of

Return will be at 14% and have a Pay Back Period of 6.8years. The result of the economic assessment of electricity generation from the two dumpsites through solid waste incineration shows that the Net Present Value is positive at electricity cost of N29.8/kWh, and the cost is comparable with a study by (Amoo et al., 2013) who found out that electrical power generation using incineration plant could provide electricity at a cost of N32.5/kWh in Lagos and Nsukka. The result therefore implies that investment is profitable at N29.8/kWh in Gombe metropolis.

CONCLUSION AND RECOMMENDATION

Conclusion

The result of the economic sustainability assessment of electricity generation from the two dumpsites (INEX and GOSEPA), through solid waste incineration shows that the Net Present Value is positive at electricity cost of N29.8/kWh, and the cost is comparable with a study by (Amoo et al., 2013) who found out that electrical power generation using incineration plant could provide electricity at a cost of N32.5/kWh in Lagos and Nsukka. The results in the tables above therefore imply that investment is profitable in Gombe metropolis at N29.8/kWh.

Recommendations

Based on the findings of this research which reveals the profitability of investment at electricity cost of N29.8/kWh, the following recommendation is made for the economic sustainability of utilizing solid waste generated in Gombe metropolis for renewable energy production:

The research recommends that INEX cleaners and Gombe State government should establish waste-to-energy plant at the two dumpsites (INEX and GOSEPA) for providing base load renewable electrical power in the State.

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