2nd International Engineering Conference (IEC 2017)
Federal University of Technology, Minna, Nigeria

Energy Potential of Food Waste Generated by A Middle Class Neigbourhood in Nigeria Through Anaerobic Digestion

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ABSTRACT

The paper assessed the energy potential of the food waste content of the municipal solid waste generated by an upper middle class neigbourhood in Abuja, Nigeria. The findings from this research should encourage the government and private institutions involved in energy generation to tow the path of developed nations and continental partners like South Africa and look towards biogas technologies as means towards ameliorating the challenges faced with fossil based fuels and effective solid waste management. From the quantification exercise the Estate has the capacity to generate about 90.23GJ of energy per year from the anaerobic digestion of the food waste generated by the occupants.

Keywords: *Waste, Management, Energy, Biogas*

1 INTRODUCTION

The world population has continued to increase geometrically and it is expected to be above 8 billion by 2025 (UN DESA, 2015). The spurt in population has put an enormous strain on the numerous natural resources of the earth particularly the world's fossil fuel reserve. Oil, coal and natural gas are all fossil fuels. These fuels have been central to industrialization and have been extensively tapped to sustain development and make the earth habitable for mankind (Bardi, 2009; De Almeida & Silva, 2009). The exploding population definitely connotes that more of these fuels would be needed to satisfy man's insatiable energy, needs and according to Hubbert King's Postulate Theory (1959), we are already past the peak production of these resources. From the same findings, it was stated that the world's fossil reserve would completely "dry-up" within the next few decades leaving us with the need to develop viable alternative sources of energy necessary to sustain life and development on earth. Apart from the depleting fossil reserves, extraction and utilization of these fuel have come with irrevocable damage on the ecosystem. A large percentage of the environmental issues the world is faced with today stem from the production and combustion of fossil fuels. Some of the problems include climate change, air pollution, oil spills that pollute arable land and water, and acid rain. Furthermore, the combustion of fossil fuels yield heat-confining gases (CO_2 and NO_2) that absorbs and emits radiation within the thermal infrared range. The process is the primary cause of greenhouse effect which is the causative factor of the rising temperature of the earth known as global warming. The destructible consequences of global warming include rising sea levels (linked to floods), ocean's acidification, drought, frequent heat waves, melting of glaciers, poorer air quality, climate change and alteration of seasons. These problems have not only threatened the existence of the human race but also depleted specific resources they depend upon for their livelihood and culture (IEA. 2015).

A number of alternative fuels have been developed and extensively utilised with biogas as a leading candidate. This is primarily because it not only ticks all the criteria to be a viable substitute fuel in the industrial and transport sector (the major energy consuming sectors) but also because biogas performs at par with petrol diesel and natural gas in internal combustion engines. Another advantage biogas has over other alternative fuels is the array of renewable sources including organic wastes from which it can be produce making it a highly cost effective to produce and with the world's waste reserves expected to reach 2.2 billion tonnes by 2025 from 1.2 billion tonnes in 2010 there is enormous potential to generate sustained commercial quantities of biogas by every country to completely substitute the traditional fuels which are petrol, diesel natural gas and coal (Hoornweg and Bhada-Tata, 2012; Larsson, 2008; Gajendra & Subramanian, 2013). For most African countries with large economies like Nigeria and South Africa, it is pertinent that they look inward to biogas generation as a means of achieving energy independence because not only does the current energy demand in these countries outweigh supply (Electricity) but it would also help with improved and effective methods of waste management (PAAR, 2016). Landfill is currently the most popular method of disposing waste in Africa. The versatility and simplicity of this method in terms of technical requirements, environmental and socio-economic aspects make it more popular than other known techniques like recycling, incineration, mechanical biological treatment and composting. That being said, landfills are often underfunded in developing countries, poorly managed and pose significant health and environmental hazards but even with the effective management systems and the latest technological advancements put in place in developed nations, landfills still pose significant risks to humans. At Landfills, human waste is compacted and buried underneath the soil which gives rise to harmful leachates and emissions. Furthermore, the relatively short life span of working landfills is also of concern because once a landfill is decommissioned (after exceeding its loading capacity), other useful arable lands are converted to less productive but necessary landfills. Another point of note is the continuous production of methane by landfills a 21 times more potent greenhouse gas than carbon dioxide, even 30 to 50 years after it has been decommissioned. However, converting organic waste streams to useful fuel (biogas) through anaerobic digesters will reduce the amount of waste that eventually gets buried at the landfills, increasing the longevity of the landfills and also provide economic benefits from the sales of energy to the immediate community (COJ_UJ_WTE_FS002, 2016).

Countries around the world continue to adopt waste-to-energy technologies, particularly the conversion of organic waste to biogas to not only reduce the use of landfills (with numerous health hazards) but also because these technologies serve as means to render the waste streams innocuous and create better and more productive utilization pathways. In many African countries currently plagued with extreme poverty, communities ought to critically consider biogas generation from the existing and sizable waste reserves as means of empowering the citizens because the processes to produce biogas is multifaceted and would provide numerous jobs, fuel and fertilizers which would definitely improve living standards (Persson & Baxter, 2014; Kukoyi et al 2015, IEA Bioenergy, 2014). Biogas generation for energy has been proven in Europe to aid efficient decentralization of energy production (a shift from the complex centralized mode of generating electricity in Africa which has yielded substandard results), immensely supplement energy generation (energy security), create income for households and communities, and efficiently improve waste management. Sweden is said import waste from neigbouring countries including the United Kingdom as they currently lead in the utilization of waste for energy. Adopting and efficiently utilizing waste to energy technologies has seen that less than 1 per cent of Swedish household waste was sent to landfills since 2011. Sweden has also drastically reduced her dependency on fossil based fuels and currently generate about 50% of her electricity from renewable sources while powering about 50% of its public vehicle fleet with biogas (IEA Bioenergy, 2014; Kukoyi & Muzenda, 2015). In Africa, The City of Johannesburg has been at the forefront of promoting the use of biogas to sustain economic development and also to reduce greenhouse gas emissions since biogas use rather than its fossil counterparts on a well-to-wheel bases would cut carbon dioxide emissions by as much as 50%. Key to the City's relative waste management success when compared to other African cities is that recent administrations have adequately sensitized the populace on the diverse numerous benefits that could be derived from household wastes while including incentives aimed at encouraging the reduction, reuse, sorting and recycling of wastes with the first three processes being encouraged at household levels. The City of Johannesburg has also partnered with numerous organizations including the University of Johannesburg in developing frameworks and structures to fully maximise biogas generated anaerobically digesting OFMSW from their 4 major landfills (COJ_UJ_WTE_FS002, 2016). It is hoped that the more developed states in Nigeria timely tow similar paths to energy recovery from the numerous waste reserves via biogas production to solve various energy inadequacies. This should however spread soonest to different states and even local communities that currently have no electrical infrastructure or are faced with crippling cost of electrical energy and fuel as is the case with many communities in the Northern and Niger Delta region of Nigeria (Akpan α & Nnamseh, 2014). This paper hopes to encourage the adoption of biogas use as an alternative fuel by estimating the energy potential from a small-scale waste- to-energy production facility. The exercise was embarked upon to determine the quantity of waste generated annually by a small community in Abuja, The Federal Capital Territory of Nigeria and to project the energy estimate that could be recovered from the waste reserve. It is salient to state that the results obtained from this exercise took into consideration just the food waste portion of the organic content of the total waste generated and this is due to the fact than in small scale biogas production, it is important to consider the simplest production process to reduce running and maintenance cost which in turn will encourage acceptability. Food waste is usually favoured in small scale production because of its ease of use (simpler sorting and processing techniques are employed before feeding the digesters when compared with other organic waste types), high organic content and high biodegradability (COJ_UJ_WTE_FS002, 2016). Furthermore, the waste quantification exercise was conducted during the dry season and there might be slight variations in results obtained during the rainy season. However, plans are in place to repeat the exercise during the colder raining season.

2 METHODOLOGY.

The quantification exercise took place in January 2016 for a period of 5 weeks (January 2nd – January 30th) at Eagleville Estate, Abuja, Nigeria, located 10.4 km northeast of the Abuja business district and about 42 km from the Nnamdi Azikiwe International airport. The Estate is made up of 63 functional houses and mid-size shopping mart inhabited by middle class families. The weekly quantification was done on Mondays just before the waste management company contracted to dispose the wastes carted away the waste streams to the landfill. The ASTM D5231-92 standards for sampling, sorting and determining waste composition was adhered to (AbdAlqader & Hamad, 2014). Samples of 100kg were randomly selected from the waste disposal vehicle (Figure 3) and discharged for manual sorting into the different weight categories. This was used to determine with mean waste composition and corresponding weight values taken over the duration of the exercise. A strategic area was mapped out with tarpaulins spread across to sort the waste samples. A 500kg capacity optimally calibrated scale was used for the exercise and 140 litre refuse bins were used to hold the different waste categories for measurement and data collection ans shown in Figure 1 and Figure 2.

Figure 1: 140 Litre refuse bins

Figure 2: A sample of the household waste generated

Figure 3: Waste collection before manually sorting

3 RESULTS

The average weekly waste generation by the occupants of the estate was deduced to be about 2.2 tonnes per week as shown in Figure 4. This was calculated values derived from the 5 week waste quantification exercise. Although the waste streams presented in Figure 5 depicts the organic content of the waste generated for the exercise to be more than 80%, the waste type of interest which is food waste was 52% of the total waste generated which is also presented in Figure 3.

The energy potential of the food waste generated was calculated according the BC BioProducts Association Estimate taking into account the average daily waste collated during the 5-week exercise (Electrigaz, 2007). The energy equivalent expected is seen in the Table 1 and Table 2 when the food waste portion of the waste is fed consistently for a year into a digester designed for its capacity (designed to accommodate its tonnage).

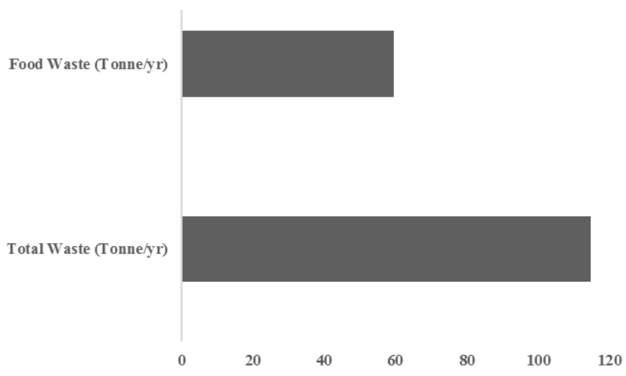

Figure 4: Estimated annual waste generation of the Estate

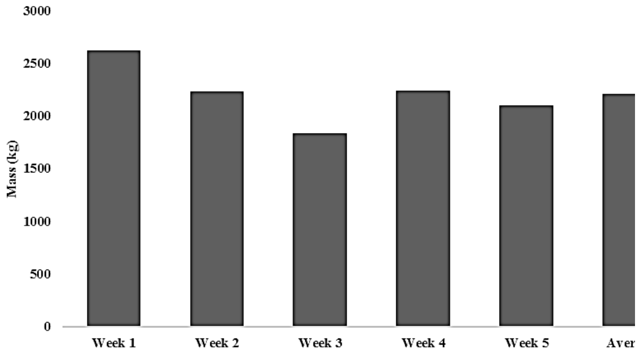

Figure 5: Quantity of waste generated from the exercise.

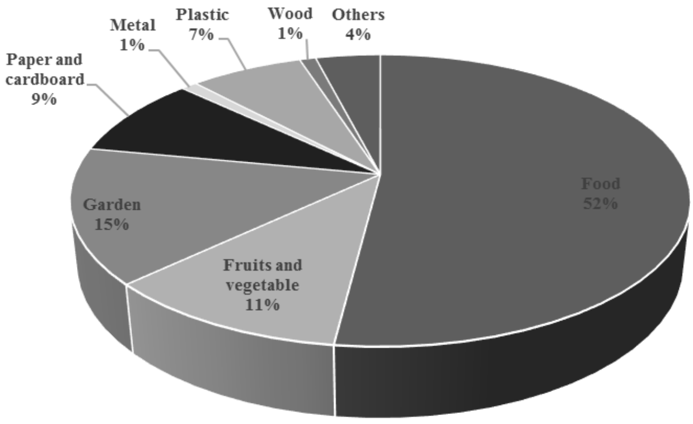

Figure 6: Percentage distribution of the waste types generated during the quantification exercise

TABLE 1: ENERGY EQUIVALENT FROM THE QUANTIFIED FOOD WASTE

Waste Type (Round collected refuse)	Quantity organic (tons/yr)	Biogas (m3/yr)	Energy (GJ/yr)	Electricity* (kWh)
Food Waste	59.67	4177.12	90.23	10025.09

TABLE 2; EQUIVALENT OF OTHER FUEL TO BIOGAS AND CO_2 REDUCTION*

Other fuel	Equivalent
Natural gas (m^3/yr)	2506.22
Diesel (l/yr)	2372.69
Petrol (l/yr)	2674.19
Electricity (MW)	0.36
CO_2 equivalent reduction (tCO_{2eq}/yr)	36.84

**Assuming biogas with 60% methane and 35% conversion efficeincy from methane to electricity*

**1 Nm^3 of biomethane equals 0.9467 l of diesel and 1.067 l of petrol.*

4 CONCLUSION

It can be deduced that household waste possess numerous economical and developmental benefits if properly harnessed for energy production. 90.23 GJ of energy and an equivalent of 2674.19 litres of petrol could be generated from food waste generated annually by the inhabitants of the relatively small community where this waste management exercise was conducted. However, if other organic constituents of the household waste like paper and cardboard waste, fruits and vegetable waste and garden waste are processed and incorporated for use in an anaerobic digester to produce biogas the projected energy potential would definitely be higher than what was obtained for this exercise. Generating and utilizing biogas will not only yield a cost effective and environmentally friendly fuel but would also help enhance energy sufficiency and independence in communities and countries that adopt its technologies.

ACKNOWLEDGMENT

The authors wish to acknowledge University of Johannesburg COJ research group, Process Energy and Environmental Technology Station (PEETS) and Botswana University of Science and Technology for technically support

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