International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

CASE STUDY

# Potential for energy recovery from municipal plastic wastes generated in Nigeria

**O.F. Olusunmade[1]*; T.A. Yusuf[1]; C.O. Ogunnigbo[2]**

[1]*Department of Mechanical Engineering, College of Engineering, Federal University of Agriculture, Makurdi, Nigeria*

[2]*Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria*

**ARTICLE INFO**

***Article History:***
Received 23 June 2019
Revised 12 August 2019
Accepted 7 September 2019

***Keywords:***
Electricity
Nigeria
Plastic wastes
Pyrolysis
Waste-to-Energy (WTE)

**ABSTRACT**

Management of municipal solid wastes (MSW) in most developed societies now involves the use of thermo-chemical conversion methods. This leads to energy and material recovery while also protecting the environment. However, till date most of the wastes generated in Nigeria (including plastic wastes) are either land-filled or openly burnt. These methods are not sustainable and environmentally non-friendly. The reason is that so much space will be needed to accommodate the ever increasing wastes as a result of land-filling and open burning leads to environmental pollution and health challenges. Also, the inherent energy in plastic wastes, as a result of the fact that they have their origins from oil and gas, is not recovered for the benefit of meeting the energy requirements of the populace. Meanwhile there is serious inadequate supply of heat and electricity, the production of which could be improved if the plastic wastes are also applied for electricity and heat generation. This study estimated the amount of energy loss due to the prevailing method of disposal adopted for plastic wastes in terms of quantity of oil and electricity that could have been produced if thermo-chemical approaches were adopted for these wastes. It showed that about 17.3 million barrels of crude oil (worth about $1 billion) and 7.1 million MWh of electricity (capable of powering 4.4 million households) could be produced from the plastic wastes generated in the country. Therefore, plastic wastes should be embraced and treated as a resource rather than "wastes".

DOI:10.22034/IJHCUM.2019.04.05


## INTRODUCTION

Globally management of the enormous and ever increasing amount of plastic wastes is of huge concerns both in developed and especially in developing societies (Koushal *et al.,* 2014). This concern is largely due to the negative impact that irresponsible and careless handling of plastic wastes has on the environment (Olusunmade *et al.*, 2018a). Since its development, plastic has played significant role in the lives of people because many products are made from the material such as household items, automotive and aerospace parts, electronics, building and construction materials, etc. As a result of certain desirable properties that plastic possesses (i.e. durability, cheap, low density, resistance to corrosion, etc.), it has successfully and consistently being used to replace traditional materials like wood, ceramics and metal in some applications (Wong *et al.*, 2015) However, the non-biodegradability of plastics makes them linger in the environment for hundreds

*Corresponding Author:
Email: *olusunmadeolusola@yahoo.com*
Tel.: +2347063474871
Fax: +2347063474871

of years. The additives that are introduced to make plastic durable are released as toxins as plastics linger in landfills into water beds poisoning humans and animals that drink the water. Open burning of these wastes also results in the pollution of the environment. Plastic wastes block water drainages leading to erosion and flooding. Eventually, they find their way to large bodies of water and cause deaths of aquatic lives (Olusunmade *et al.*, 2018b) who feed on them "imagining" they are foods. Tons of plastic wastes in landfill also create horrible sights, particularly in developing societies where landfills are not properly managed. Because of the danger that plastic wastes pose, there is need to develop responsible waste management policies that will protect the environment from these wastes. With the emergence of new approaches to waste management (pyrolysis, gasification and waste-to-energy), plastic wastes is now gradually being seen as a resource rather than a problem, because of the possibility of material and energy recovery that could result from these wastes. Plastics are obtained by the synthesis of chemicals derived from natural gas/ crude oil (ACC, 2005; Al-Salem, 2010). The production process for plastics starts with the distillation of crude oil in a refinery. This allows the heavy crude oil to break down into lighter components referred to as fractions. One of these fractions, naphtha, is an important feedstock of choice for plastic production (PlasticsEurope, 2018). Naphtha is processed in furnaces with high temperatures to obtain ethane and propane which are subsequently cracked into ethylene and propylene respectively to produce plastic polymers (polyethylene and polypropylene). Many of the other plastics available for use today are made from these polymers (Plastisisrubbish, 2013). The fact that plastics have their origin from petroleum shows that they possess some energy trapped within (Olusunmade, 2019), which is lost when we just dispose of them in landfill. Applying these techniques could simultaneously help militate against the danger of plastic wastes on the environment while also producing the energy that is not so available. In Nigeria, the commonly adopted management method for plastic wastes is landfill and open burning (Olusunmade, 2019). This results in the loss of valuable energy opportunities that could be derived from these "resource". This report, therefore, examined the potential for energy recovery from landfill plastic wastes in Nigeria by establishing the amount of these wastes generated annually within a period and hence estimated the energy loss as a result of that choice of waste management practice. Nigeria is the world's 29th largest economy as of 2019, worth about $500 billion of nominal GDP (Statistics Times, 2019) and is considered to be an emerging market and global power. As a result of economic development and population growth, waste management is a major challenge in Nigeria. This problem is attributable to indiscriminate disposal of wastes by the populace and inability of municipal councils to effectively manage the resulting rise in industrial and domestic waste (Olusunmade, 2019). This study has been carried out in Nigeria in 2019.

## MATERIALS AND METHOD

*Description of the study area*

Nigeria is a country in West Africa, bordering Niger in the north, Chad in the northeast, Cameroon in the east, and Benin in the west. Its coast in the south is located on the Gulf of Guinea in the Atlantic Ocean. It lays between longitudes 3 and 14 degrees and latitudes 4 and 140 degrees. The land mass of the country is 923,768 sq. km. and is divided into 36 states and a Federal Capital Territory (FCT) as can be seen in Fig. 1. It is the most populous country in Africa and the seventh most populous country in the world.

*Research design*

It is generally assumed that as a country advances economically and its population grows, there is an increase in the per capita waste generation rates i.e. there is a linear relationship between GDP per capita and waste generation. The model adopted in this study uses the World Bank's Development indicator's GDP per capita to determine the per capita waste generation rate and the total annual waste generation in the country. The model was developed using the available baseline waste generation data in the country and the GDP per capita from the associated year. A linear regression method was developed to predict the waste generation in any specified year given the GDP per capita for that year. Oguntoyinbo (2012) estimated that the amount of waste generated in Nigeria in 2009 is 27,614,830 tons. Kaza *et al.*, (2018) puts the waste generated per person daily in the country as of 2016 to be 0.51kg. Considering the population of Nigeria for 2016 from World Bank


Fig. 1: Geographic location of the study area in Nigeria showing all 36 States and FCT

open data, which was estimated at 185,989,640, the amount of waste generated by the country amounted to 34,620,000 tons. Using these baselines, a regression model was developed.

Annual Waste Generated/Person=0.025 (GDP per capita)+130.4

## RESULTS AND DISCUSSION

*Wastes generation in Nigeria*

It was estimated by the World Bank Group that the amount of plastic wastes in MSW is about 8-12% in different countries of the world (Hoornweg and Bhada-Tata, 2012) while in Sub-Sahara Africa, a region which Nigeria belongs, it accounts for 11% of the total MSW (Kaza *et al.*, 2018). Using this estimate and applying the model developed, the plastic wastes and the overall MSW generated in Nigeria from 2000 to 2018 was determined and are presented in Table 1. Estimates of plastic wastes in different States and Federal Capital Territory (FCT) of the country in 2016 are also shown in Table 2, according to the population figures available from the Nigeria Bureau of Statistics (NBS, 2017).

Table 1: Estimates of waste generated in Nigeria between 2000 and 2018

| Year | GDP per capita ($) | Amount of waste generated (tons) | Amount of plastic wastes generated (tons) |
|---|---|---|---|
| 2018 | 2049 | 35,961,750.00 | 3,955,792.500 |
| 2017 | 1968.4 | 34,285,090.14 | 3,771,359.915 |
| 2016 | 2175.7 | 34,369,490.55 | 3,780,643.960 |
| 2015 | 2729.8 | 35,990,846.74 | 3,958,993.142 |
| 2014 | 3221.7 | 37,223,019.02 | 4,094,532.092 |
| 2013 | 2997.0 | 35,280,851.02 | 3,880,893.612 |
| 2012 | 2745.9 | 33,300,105.34 | 3,663,011.587 |
| 2011 | 2519.3 | 31,497,576.92 | 3,464,733.462 |
| 2010 | 2291.4 | 29,762,760.73 | 3,273,903.680 |
| 2009 | 1890.4 | 27,431,091.30 | 3,017,420.043 |
| 2008 | 2241.7 | 28,031,143.26 | 3,083,425.759 |
| 2007 | 1882.5 | 25,983,530.41 | 2,858,188.345 |
| 2006 | 1655.5 | 24,499,317.99 | 2,694,924.978 |
| 2005 | 1267.7 | 22,521,047.66 | 2,477,315.243 |
| 2004 | 1007.3 | 21,064,877.88 | 2,317,136.567 |
| 2003 | 795.0 | 19,832,171.95 | 2,181,538.914 |
| 2002 | 741.3 | 19,162,654.79 | 2,107,892.027 |
| 2001 | 590.1 | 18,211,330.52 | 2,003,246.358 |
| 2000 | 567.6 | 17,690,877.13 | 1,945,996.484 |

Table 2: Plastic wastes generation in Nigerian States and FCT in 2016

| State | Population | Amount of plastic wastes generated (tons) |
|---|---|---|
| Abuja | 3,564,126 | 72390.78498 |
| Abia | 3,727,347 | 75705.95855 |
| Adamawa | 4,248,436 | 86289.77117 |
| Akwa Ibom | 5,482,177 | 111348.2229 |
| Anambra | 5,527,809 | 112275.0522 |
| Bauchi | 6,537,314 | 132779.0578 |
| Bayelsa | 2,277,961 | 46267.55197 |
| Benue | 5,741,815 | 116621.7174 |
| Borno | 5,860,183 | 119025.8839 |
| Cross River | 3,866,269 | 78527.59635 |
| Delta | 5,663,362 | 115028.2624 |
| Ebonyi | 2,880,383 | 58503.31509 |
| Edo | 4,235,595 | 86028.95827 |
| Ekiti | 3,270,798 | 66433.01464 |
| Enugu | 4,411,119 | 89594.01745 |
| Gombe | 3,256,962 | 66151.99233 |
| Imo | 5,408,756 | 109856.9727 |
| Jigawa | 5,828,163 | 118375.5273 |
| Kaduna | 8,252,366 | 167613.3932 |
| Kano | 13,076,892 | 265604.0996 |
| Katsina | 7,831,319 | 159061.5286 |
| Kebbi | 4,440,050 | 90181.63355 |
| Kogi | 4,473,490 | 90860.83172 |
| Kwara | 3,192,893 | 64850.69008 |
| Lagos | 12,550,598 | 254914.5684 |
| Nassarawa | 2,523,395 | 51252.54968 |
| Niger | 5,556,247 | 112852.655 |
| Ogun | 5,217,716 | 105976.7688 |
| Ondo | 4,671,695 | 94886.56356 |
| Osun | 4,705,589 | 95574.9829 |
| Oyo | 7,840,864 | 159255.3967 |
| Plateau | 4,200,442 | 85314.96744 |
| Rivers | 7,303,924 | 148349.6352 |
| Sokoto | 4,998,090 | 101515.9561 |
| Taraba | 3,066,834 | 62290.31203 |
| Yobe | 3,294,137 | 66907.0519 |
| Zamfara | 4,515,427 | 91712.61203 |
| Total | 193,500,543 | 3,930,179.854 |

*Energy potential from plastic wastes in Nigeria*

As previously highlighted, the waste management system in the country does not include energy recovery from generated wastes (including plastic), as it relies solely on landfill and open burning. However, in many developed cities in the world, energy is recovered from non-recycled plastic (NRP) which could have been sent landfills at waste-to-energy (WTE) facilities by combustion to generate steam and electricity (GBB, 2013; Wienenergie, 2014); by pyrolysis to produce oil and by gasification to produce syngas. In 2011, an estimated 3.9 million tons of plastic wastes were processed in this ways in the US (Themelis and Mussche, 2014). Municipal plastic wastes consist primarily of LDPE, HDPE, PET, PP, PS and PVC and about 50-70% of the total plastic wastes is packaging materials derived from these types of plastics (Kunwar *et al.*, 2016). Table 3 presents the energy content of these plastics prevalent in MSW in

Table 3: Low heating value of plastic materials (Themelis and Mussche, 2014)

| Plastic waste material | LHV (MJ/kg) | LHV (Million Btu/ton) |
|---|---|---|
| PET | 23.9 | 20.5 |
| HDPE | 44.3 | 38.0 |
| PVC | 19.2 | 16.5 |
| LDPE | 44.3 | 38.0 |
| PP | 44.3 | 38.0 |
| PS | 41.5 | 35.6 |

Table 4: Typical MSW plastic wastes composition (Bodzay and Banhegyi, 2016; Themelis and Mussche, 2014)

| Plastic wastes composition | % in plastic wastes | LHV of plastic types (MJ/kg) | Plastic wastes fraction LHV (MJ/kg) | Plastic wastes fraction LHV (Million Btu/ton) |
|---|---|---|---|---|
| PET | 10% | 23.9 | 2.4 | 2.1 |
| HDPE | 19% | 44.3 | 8.4 | 7.2 |
| PVC | 6% | 19.2 | 1.2 | 1.0 |
| LDPE | 23% | 44.3 | 10.2 | 8.7 |
| PP | 14% | 44.3 | 6.2 | 5.3 |
| PS | 9% | 41.5 | 3.7 | 3.2 |
| Others | 19% | 25.0 | 4.8 | 4.1 |
| Total plastic wastes | 100% | | 36.9 | 31.6 |

Table 5: Energy equivalent of plastic wastes generated in different States of Nigeria in 2016

| State | Amount of plastic wastes generated (tons) | LHV (Million Btu/ton) | Barrel of Oil equivalent (BoE) | Electricity equivalent (MWh) |
|---|---|---|---|---|
| Abuja | 72390.78498 | 2287548.805 | 393805.8703 | 130303.413 |
| Abia | 75705.95855 | 2392308.29 | 411840.4145 | 136270.7254 |
| Adamawa | 86289.77117 | 2726756.769 | 469416.3552 | 155321.5881 |
| Akwa Ibom | 111348.2229 | 3518603.845 | 605734.3328 | 200426.8013 |
| Anambra | 112275.0522 | 3547891.65 | 610776.284 | 202095.094 |
| Bauchi | 132779.0578 | 4195818.226 | 722318.0744 | 239002.304 |
| Bayelsa | 46267.55197 | 1462054.642 | 251695.4827 | 83281.59355 |
| Benue | 116621.7174 | 3685246.269 | 634422.1425 | 209919.0913 |
| Borno | 119025.8839 | 3761217.931 | 647500.8084 | 214246.591 |
| Cross River | 78527.59635 | 2481472.045 | 427190.1241 | 141349.6734 |
| Delta | 115028.2624 | 3634893.092 | 625753.7475 | 207050.8723 |
| Ebonyi | 58503.31509 | 1848704.757 | 318258.0341 | 105305.9672 |
| Edo | 86028.95827 | 2718515.081 | 467997.533 | 154852.1249 |
| Ekiti | 66433.01464 | 2099283.263 | 361395.5996 | 119579.4263 |
| Enugu | 89594.01745 | 2831170.952 | 487391.4549 | 161269.2314 |
| Gombe | 66151.99233 | 2090402.958 | 359866.8383 | 119073.5862 |
| Imo | 109856.9727 | 3471480.337 | 597621.9314 | 197742.5508 |
| Jigawa | 118375.5273 | 3740666.662 | 643962.8684 | 213075.9491 |
| Kaduna | 167613.3932 | 5296583.225 | 911816.859 | 301704.1078 |
| Kano | 265604.0996 | 8393089.546 | 1444886.302 | 478087.3792 |
| Katsina | 159061.5286 | 5026344.305 | 865294.7158 | 286310.7516 |
| Kebbi | 90181.63355 | 2849739.62 | 490588.0865 | 162326.9404 |
| Kogi | 90860.83172 | 2871202.282 | 494282.9245 | 163549.4971 |
| Kwara | 64850.69008 | 2049281.806 | 352787.754 | 116731.2421 |
| Lagos | 254914.5684 | 8055300.363 | 1386735.252 | 458846.2232 |
| Nassarawa | 51252.54968 | 1619580.57 | 278813.8702 | 92254.58942 |
| Niger | 112852.655 | 3566143.898 | 613918.4432 | 203134.779 |
| Ogun | 105976.7688 | 3348865.894 | 576513.6222 | 190758.1838 |
| Ondo | 94886.56356 | 2998415.409 | 516182.9058 | 170795.8144 |
| Osun | 95574.9829 | 3020169.46 | 519927.907 | 172034.9692 |
| Oyo | 159255.3967 | 5032470.534 | 866349.3578 | 286659.714 |
| Plateau | 85314.96744 | 2695952.971 | 464113.4229 | 153566.9414 |
| Rivers | 148349.6352 | 4687848.471 | 807022.0153 | 267029.3433 |
| Sokoto | 101515.9561 | 3207904.212 | 552246.8011 | 182728.721 |
| Taraba | 62290.31203 | 1968373.86 | 338859.2975 | 112122.5617 |
| Yobe | 66907.0519 | 2114262.84 | 363974.3623 | 120432.6934 |
| Zamfara | 91712.61203 | 2898118.54 | 498916.6094 | 165082.7016 |
| Total | 3,930,179.854 | 124,193,683.4 | 21,380,178.4 | 7,074,323.737 |

terms of the lower heating value (LHV).

Table 4 shows the typical composition of plastic wastes in MSW and the average low heating value (LHV) of the major constituents.

This shows that for every ton of plastic wastes there is equivalent energy content of 31.6 million Btu. When compared with other available fuels, a ton of plastic wastes represents 5.44 barrels of oil, 30680 standard cubic feet of natural gas and 1.44 tons of coal since 1 barrel of oil equals 5.8 million Btu, 1000 standard cubic feet of natural gas equals 1.03 million Btu and 1 ton of coal equals 22 million Btu (Themelis and Mussche, 2014). Based on these estimates, Table 5 presents the energy potential of all the States and FCT in Nigeria according to their plastic wastes generation as at 2016.

*Energy generation potential via plastic wastes pyrolysis route*

Pyrolysis is the thermo-chemical decomposition of organic (carbon-based) materials. It is the first step in gasification and combustion and occurs in the absence or near absence of oxygen to produce predominantly oils and some gases. In industrial applications the temperatures used are often 430 °C or higher (Boslaugh, 2018). Assuming all the plastic wastes generated in 2018 in the country were converted to energy rather than sent to landfill, the energy generated would have amounted to (3,955,792.5*31.6) Million Btu = 125003043Million Btu = 21.6 million barrels of oil. However, a realistic thermal efficiency of pyrolysis plants is 80% (4R Sustainability, 2011; Haig *et al.*, 2018). This means that one ton of plastic wastes will produce 4.35 barrels of oil. As such the plastic wastes generated in 2018 would have resulted in the production of 17.3 million barrels of crude oil. In 2018, a barrel of oil costs $70 (Garside, 2019). Therefore, the worth of the crude oil produced from the process of pyrolysis of plastic wastes in 2018 would be about $1 billion.

*Energy generation potential via waste-to-electricity route*

In waste-to-energy (WTE) plants, wastes is burnt in a combustion chamber and the resulting heat is used to generate steam, which is then used power a turbine generator that produces electricity (UNEP, 2017). New WTE plants have the capacity to generate 0.6MWh/ton of MSW. The fact that the LHV of plastic wastes is about 3 times higher than that of MSW means the combustion of plastic wastes in such WTE plants will lead to the generation of about 1.8MWh of electricity/ton of plastic wastes (Themelis and Mussche, 2014). The conversion of all the plastic wastes generated in 2018 in the country, would produce (3955792.5*1.8MWh) = 7.1 million MWh of electricity. Olaniyan *et al.*, (2018) estimated electricity consumption per capita in Nigeria at an average value 0.324MWh per annum. The average number of persons in a Nigerian household is 5 (NPC, 2013). Therefore, the electricity consumption by a household will be (0.324MWh*5) =1.62MWh. This showed that the amount of electricity from the plastic wastes generated in the country is able to power 4.4 million households.

## CONCLUSION

Most of the wastes generated in Nigeria (including plastics) are either land-filled or openly burnt. These methods are not sustainable and environmentally non-friendly. So much space will be needed to accommodate the ever increasing wastes as a result of land-filling. Open burning leads to environmental pollution and health challenges. Also, the inherent energy in plastic wastes is not recovered for the benefit of meeting the energy requirements of the populace. This study estimated the amount of energy loss from the method of disposal currently adopted for management of plastic wastes, in terms of quantity of oil and electricity that could have been produced if thermo-chemical approaches are utilized for these wastes. It showed that about 17.3 million barrels of crude oil (worth about $1 billion) and 7.1 million MWh of electricity (capable of powering 4.4 million households) could be produced from the plastic wastes generated in the country. It is therefore important at this present time that all stakeholders involved in waste management begin to see and treat plastic wastes as a resource rather than "wastes". The adoption of thermo-chemical conversion methods will lead to getting value of these materials and therefore a necessity.

## ACKNOWLEDGMENT

The authors express profound gratitude to their dear families for their support and understanding.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

## ABBREVIATIONS

| | |
|---|---|
| MSW | Municipal Solid Wastes |
| MWh | Megawatt-Hour |
| $ | US Dollar |
| ACC | American Chemistry Council |
| FCT | Federal Capital Territory |
| GDP | Gross Domestic Product |
| Kg | Kilogram |
| NBS | Nigeria Bureau of Statistics |
| NRP | Non Recycled Plastics |
| WTE | Waste to Energy |
| LDPE | Low Density Polyethylene |
| HDPE | High Density Polyethylene |
| PET | Polyethylene terephthalate |
| PP | Polypropylene |
| PS | Polystyrene |
| PVC | Polyvinyl chloride |
| LHV | Low Heating Value |
| MJ | MegaJoule |
| kWh | KiloWatt-Hour |
| BoE | Barrel of Oil Equivalent |
| UNEP | United Nation Environmental Programme |

## REFERENCES


4R Sustainability, (2011). Conversion technology: A complement to plastic recycling. American Chemistry Council.

ACC, (2005). How plastics are made. American Chemistry Council.

Al-Salem, S.M.; Lettieri, P.; Baeyens, J., (2010). The valorization of plastic solid waste (PSW) by primary to quaternary routes: From re-use to energy and chemicals. Prog. Energy Combust. Sci., 36(1): 103-129 **(27 pages).**

Boslaugh, S.E., (2018). Pyrolysis. Encyclopædia Britannica.

Brigitta, B.; György, B., (2016). Polymer waste: Controlled breakdown or recycling? Int. J. Des. Sci. Tech., 22: 109-138 **(20 pages).**

Bodzay, B.; Bánhegyi, G., (2016). Polymer waste: controlled breakdown or recycling?. Int. J. Des. Sci. Tech., 22(2).

Garside, M., (2019). OPEC oil price annually 1960-2019. Statistica.

GBB, (2013). Gasification of Non-Recycled Plastics from Municipal Solid Waste in the United States. The American Chemistry Council.

Haig, S.; Morrish, L.; Morton, R.; Onwuamaegbu, U.; Speller, P.; Wilkinson, S., (2018). Plastics to oil products: Final report. Zero Waste Scotland.

Hoornweg, D.; Bhada-Tata, P., (2012). What a Waste: A Global Review of Solid Waste Management. Urban development series; knowledge papers no. 15. World Bank, Washington, DC.© World Bank.

Kaza, S.; Yao, L. C.; Bhada-Tata, P.; Van Woerden, F., (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development; Washington, DC: World Bank. © World Bank.

Koushal, V.; Sharma, R.; Sharma, M.; Sharma, R.; Sharma, V., (2014). Plastics: Issues Challenges and Remediation. Int. J. Waste Res.., 4(1): 1-6 **(5 pages).**

Kunwar, B; Cheng, H. N.; Sriram, R. C.; Brajendra K. S., (2016). Plastics to fuel: a review. Renewable and Sustainable Energy Reviews, 54: 421–428 **(8 pages).**

NBS, (2017). Demographic Statistics Bulletin. National Bureau of Statistics.

NPC (2013). Nigeria Demographic and Health Survey. Nigeria Population Commission.

Oguntoyinbo, O., (2012). Informal waste management system in Nigeria and barriers to an inclusive modern waste management system: A review. Public Health, 126 (5): 441-447 (**7 pages**).

Olaniyan, K.; McLellan, B.C.; Ogata, S.; Tezuka, T., (2018). Estimating Residential Electricity Consumption in Nigeria to Support Energy Transitions. Sustainability, 10(5): 1-22 (**22 pages**).

Olusunmade, O. F., (2019). Plastic wastes separation practice and disposal mechanism by households, hospitals, markets and waste management body. Int. J. Hum. Capital Urban Manage., 4(3): 189-204 (**16 pages**).

Olusunmade, O. F.; Bulus, A. E.; Kashin, T. K., (2018). Effect of Imperata Cylindrica (IC) reinforcement form on the tensile and impact properties of its composites with recycled low density polyethylene (RLDPE). ACTA Polytechnica, 58(5):292-296 **(5 pages).**

Olusunmade, O. F.; Zechariah, S.; Yusuf, T. A., (2018). Characterization of Recycled Linear Density Polyethylene/Imperata Cylindrica Particulate Composites. ACTA Polytechnica, 58(3): 195-200 **(6 pages).**

Plasticisrubbish, (2013). Naphtha and Oil derived plastics.

PlasticsEurope, (2018). How plastics are made.

Statistics Times, (2019). World Gdp Ranking 2019.

Themelis, N.; Mussche, C., (2014). Energy and economic value of municipal solid waste (MSW), including non-recycled plastics (NRP), currently landfilled in the fifty states. USA: Earth Engineering Center. 1-40 (**40 pages**).

UNEP, (2017). Ethiopia's waste-to-energy plant is a first in Africa. United Nation Environmental Programme.

Wienenergie, (2014). "Spittelau - The thermal waste treatment plant", Technical Brochure.

Wong, S.L.; Ngadi N.; Abdullah T.A.T.; Inuwa I.M., (2015). Current state and future prospects of plastic waste as source of fuel: a review. Renew Sustain Energy, 50:1167–80 **(14 pages).**

**HOW TO CITE THIS ARTICLE**

*Olusunmade, O.F., Yusuf, T.A., Ogunnigbo, C.O.; (2019). Potential for energy recovery from municipal plastic wastes generated in Nigeria. Int. J. Hum. Capital Urban Manage., 4(4): 295-302.*

**DOI:** 10.22034/IJHCUM.2019.04.05

**url:** http://www.ijhcum.net/article_36182.html