Abstract—This paper presents the strategy of improving energy generation in Nigeria by using combustible waste as alternative fuel in power plant. Household and commercial waste is being considered as fuel for electrical power generation. Data obtained include volume of waste produce in sampled building of urban, sub-urban and rural communities from field source through direct collection of total waste produce per building in each community considered. Sample of waste was measured and classified by percentage to determine the percentage combustible wood related waste usable as fuel in the power plant. Estimated combustible waste in Edo state is 360,224 Kg per day while in Ondo state 376,228.3 Kg per day which can independently run a 1Mw waste power plant on daily basis. The process flow diagram and the energy conversion strategy to be deployed is discussed.

Index Terms—Household, commercial, waste, combustible, fuel, generation, power plant.

I. INTRODUCTION

Energy is the ability to do work; it is important in all sectors of the economy. The standard of living in a given country can be directly related to the per energy consumption (Nag, 2007). Energy appears in many forms but exhibit the ability to produce vital effect in common. It exists in multiple forms: mechanical, thermal, chemical, sound, electrical, to mention a few. One form of energy can be converted into another by the use of suitable technology. Bulk electrical power is produced by special plant known as generating station. The generation stations in Nigeria are predominantly gas thermal station utilising natural gas as fuel.

The Alternative fuel considered in this paper is combustible waste generated at domestic and commercial premises. The energy conversion strategy is also presented using Edo and Ondo states as a case study.

II. METHODOLOGY

A. Alternative Fuel

The Alternative fuel considered for this studies are wood related combustible waste generated at home.

B. Data Collection of House hold waste

According to Babayemi et al (2009) volume of waste generated per person per day in different Nigerian cities are as follows: Abeokuta 0.66 Kg, Ado Ekiti, 0.71 Kg, Akure 0.54 Kg, Ile-Ife 0.46 Kg, Ibadan 0.7 Kg, Benin City 0.54 Kg, Abuja 0.58 Kg and the Lagos State management authority estimated the volume of waste generated per person per day to be 0.5 Kg in Lagos. To further using this fact, a sample was taken in Ondo and Edo States in urban, sub-urban and rural areas. 100 building were selected in the urban and sub-urban and 40 building in the rural areas to estimate the volume of waste generated per person in both States. Akure was classified as urban, Ifon sub-urban and Eporo as rural settlement in Ondo State while in Edo State, Benin city is classified as urban, Sabogida Ora sub-urban and Agbanikaka as rural community.

As data were obtained from field source through direct collection of total waste generated per building in each of the various communities considered. The numbers of occupants in the building are identified to determine the overall waste generated per person. Building sample were taken from Ugboowo, Aduwawa, New Benin and GRA in Benin City, while in Akure, Ijoka, Aule Okejebu and Alagbaka area were considered. Sample of waste was measured and classified by percentage composition, food, plastic, paper, metal, glass, classified combustible and unclassified combustible (Dennis, 2012) to determine the percentage combustion and usable as fuel for this power plant. Figures 1-3 and 4-6 show data sample of waste generated per building in Ondo and Edo state respectively.

Combustible waste consider as fuel in this category is sum of composition of paper, leaf and unclassified combustible.

Figure 1: Classification of waste by percentage in Akure Ondo State (Urban)

Figure 2: Classification of waste by percentage in Ijesa Ondo State (Sub-Urban)

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III. EVALUATION OF COMBUSTIBLE WASTE GENERATED IN ONDO STATE

Table 1 show population distribution in percentage by urban, sub urban and rural settlement.

<table>
<thead>
<tr>
<th>Description of settlement</th>
<th>Percentage distribution (PD)</th>
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<td>Urban</td>
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Population of Ondo State is 3,460,877 (Federal ministry of statistics)

Table 1: Population distribution in % by urban, sub urban and rural settlement (source federal ministry of statistics)

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Population of Ondo State is 3,460,877 (Federal ministry of statistics)

UP in Ondo State = PD x TP = 39.08 x 3,460,877 = 1,352,511
SUP = 15.53 x 3,460,877 = 537,747
RP = 45.40 x 3,460,877 = 1,571,238

UW = UP x AWG/P = 1,352,511 x 0.464 = 628,511.8617kg
CWCF in urban = 628,511.861 X 0.1994 = 125,325.27kg

SUW = SUP x AWG/P = 537,747 x 0.64 = 344,299.048kg
CWCF in sub urban = SUW x %CWCF = 344,299.048 x 0.21 = 73,243.95kg

RW = RP x AWG/P = 1,571,238 x 0.38 = 597,070.44kg
CWCF in rural = RW x % CWCF = 597,070.44 x 0.285 = 170,165.07kg

TCWG in Ondo State = 125,325.27 + 344,299.048 + 170,165.07 = 371,864.72Kg per day.

Evaluation of Combustible Waste Generated in Edo state

Population (TP) in Edo State = 3,233,366 (Federal ministry of statistics)

UP = TP x PD (Table 3.7) = 39.08 x 3,233,366 = 1,263,600
SUP = TP x PD = 15.53 x 3,233,366 = 501,818
RP = TP x PD = 45.40 x 3,233,366 = 1,467,948

UW = UP x AWG/P = 1,263,600 x 0.4984 = 628,511.8617kg
CWCF in urban = UW x % CWCF = 628,511.861 x 0.21 = 132,253.95kg

SUW = SUP x AWG/P = 537,747 x 0.64 = 344,299.048kg
CWCF in sub urban = SUW x % CWCF = 344,299.048 x 0.202 = 69,243.88kg

RW = RP x AWG/P = 1,571,238 x 0.38 = 597,070.44kg
CWCF in rural = RW x % CWCF = 597,070.44 x 0.276 = 163,682.1kg

Total combustible waste generated in Edo State = 132,253.95 + 69,243.88 + 163,682.1 = 363,221.04 kg/day.

A. Fuel and Combustion

Fuel refers to a substance that burns in air to produce carbon IV Oxide, water vapour and light with evolution of heat.

To be classed as a fuel, a material must contain elements which will combine rapidly with oxygen to initiate combustion. Substances are classed as fuels based on different yardsticks; they may be classed according to whether they are in a solid, liquid or gaseous state. In this paper attention would be focused on wood related waste with under-listed percentage chemical composition bymass: 49% C, 6% H₂O; 44% O₂; 0.4% N₂ and 0.6% Ash.

Wood burns more clearly than oil or coal and causes much less pollution. A few wood burning power plants are operating in USA (Nag, 2009; pg. 167). Combustion is the high temperature oxidation of the combustible elements (C, H₂, S etc.) fuel with heat release proper control of the right
The amount of excess air enhances optimum combustion efficiency. The amount of excess air supplied varies with the type of fuel and the firing conditions; it may approach a value of 100% but modern practice tends to use 20% to 50% excess air (Rajput, 2011.). Let the excess air be 20%.

**Step III: Air Requirement**

### Table 2: Computation of mass of Flue Gas per kg of fuel at 20% excess air

<table>
<thead>
<tr>
<th>FUEL (kg)</th>
<th>O₂ Required</th>
<th>Dry Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>C = 0.40</td>
<td>C + O₂ = CO₂</td>
<td>0.49 x (\frac{100}{22}) = 1.79666667 (CO₂)</td>
</tr>
<tr>
<td>H₂ = 0.06</td>
<td>H₂ + O₂ = H₂O</td>
<td>0.06 x (\frac{18}{2}) = 0.54 (H₂O)</td>
</tr>
<tr>
<td>N₂ = 0.004</td>
<td>-</td>
<td>0.004 (N₂)</td>
</tr>
<tr>
<td>O₂ = 0.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ash = 0.006</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1.78666667</td>
<td></td>
</tr>
</tbody>
</table>

Mass of O₂ to be supplied = Mass of O₂ supplied – Mass of O₂ already present = 1.78666667 – 0.44 = 1.34666667 kg/kg fuel

Stoichiometric air required, which is equal to the minimum mass (volume) of air required.

Minimum mass of Air supplied = \(1.34666667 x \frac{100}{22}\) = 5.855072764 kg

At 20% O₂, excess air supplied = 5.855072764 x 1.2 = 7.026086957 kg

N₂ present in the air = 7.026086957 x \(\frac{77}{100}\) = 5.416086907 kg

Total mass of N₂ present in the flue gas = 5.416086907 + 0.004 = 5.414086257 kg/kg waste wood

Mass of free O₂ due to excess air = 5.855072764 x 0.2 x \(\frac{28}{44}\) = 0.26933333 kg/kg waste wood

Mass of dry flue gas = MCO₂ + MN₂ + MO₂

= 1.70666667 + 5.414086257 + 0.26933333

= 7.480086258 kg/kg waste wood

### Table 3: Volumetric Analysis of fuel at 20% excess air

<table>
<thead>
<tr>
<th>Reactant</th>
<th>Reaction</th>
<th>Product (Mole Vol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>C + O₂ = CO₂</td>
<td>4.08333333</td>
</tr>
<tr>
<td>H₂</td>
<td>H₂ + (\frac{1}{2})O₂ = H₂O</td>
<td>3.0</td>
</tr>
<tr>
<td>O₂</td>
<td>0.8416666668</td>
<td></td>
</tr>
<tr>
<td>N₂</td>
<td>3.3388690473</td>
<td></td>
</tr>
</tbody>
</table>

Therefore, the specific weight of flue gas = \(\frac{354.088333333}{2.822}\) = 1.403382343 kg/Nm³

Calorific value: this refers to the heat energy released by the complete burning of unit quantity of fuel; it is also called specific energy or heat rate. The heat rate of solid substances is determined with Calorimeter.

**Step III: Air Requirement**

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Improving Energy Generation in Nigeria by Using Combustible Waste as Alternative Fuel

The values of Heat of combustion were obtained from heat of combustion Table. According to Dulong, the heat of evaporation of \((2 \times 0.84416666668)\) \(1.68333333\) mol/vol of water should be subtracted from this Calculated Value (CV). Hence, the calorific value of waste wood is 3, 841.89 kcal/kg (16, 085.74221kJ/kg). The calorific value calculated based on the constituents of the fuel used is called

C. Fuel Analysis for one MW-h power plant

Calorific value of wood related fuel = 16086 (Nag 2008)

Mass of fuel per hour = 3.479997888 (Nag 2008)

Mass of fuel required per day = 83.51994 t/hr

Mass of fuel required per year = 30,484.78 t/hr

Estimated MW-h of Energy Generation from Domestic Waste

(i) In Ondo State

Available combustible waste (Paper, leave and classified combustible) = 376, 340.3kg/day
376, 340.3 x 365 = 137, 364.2097 ton/yr
Generating Plant fuel usage = 118, 742.6899ton/yr

MW-h of energy that can be generated using domestic waste = 

\[
\frac{137364.2097}{118742.6899} = 1.1568 - h \approx 1.0 MW-h
\]

In Ondo State, a 1.0 MW-h Power Plant could be run for 1 year using combustible waste

(ii) In Edo State

Available combustible waste = 360.223 kg/day
(360.223 ton/day)

= 360.223 x 365 = 131481.395 ton yr

MW-h of energy that can be generated

\[
\frac{131481.395}{118742.6899} = 1.10727991 \approx 1.0 MW-h
\]

FIGURE 8, PROCESS FLOW OF ONE MEGAWATT HOUR WASTEFUEL POWER PLANT

The waste to power generation system will convert commercial, municipal, industrial waste, wood and palm kernel residue to heat with added benefit of generating electricity. The process flow diagram (PFD) is shown in fig 8

A. Waste Preparation:

Municipal and industrial waste contains varying degrees of water. It is necessary to remove this water from waste prior to injecting it into waste segregating unit. The useable portion is first dried in ambient condition and later through rotary dryer to remove bond water within the waste matrix.

This set of waste is feed into the shredding machine. Reducing them to smaller size which passes through the screw feed system into the fire box.

B. Screw feeder/spreader:

It consists of a helicoids screw fitted to a shell. The driving mechanism is connected to one end of the shell and the other end is suspended in an enclosed ball bearing. The screw while rotating in a trough housing transfer fuel from the input and to the outlet which is connected to an opening to the over feed shoker in the firebox. Below the opening is an air inlet, a branch from the ID fan help to spread the fuel on the stroker. This function as the fuel spreader.

C. Waste conversion:

The waste conversion is utilizing the stored heat value in the waste. The combustion of fuel in air to produce heat is exhibited in this stage.

The process is characterized with flame impregnated in the furnace. This unit consist of overfeed stroker firebox induced and force draught system.
**D. Overfeed stroker:**
It consists of induced draft system, forced draft, wind Box air duct, air nozzles, Fan, driving motor and blower. Fuel is delivered to the grate from the feeder and spreader powered by a motor driven variable speed driver. The grate which is an assembly of perforated cast iron section called Tuyere is positioned on top of the wind box. The combustion air is supplied to the grate through the wind box and the tuyeres from the ID fan. Sea sand are placed on the tuyere as combustion bed to serve as refractory material to sustain the temperature of the fuel and separate tuyere from heat of combustion. American standard book for boiler and Elloth 1980 explain that when using stroker boiler, output is reduced by 42% and large amount of air are required for combustion. This is compensated for with the size and rating of fan to overcome this feature two air system are deployed ID fan and FD fan.

**E. The forced air system**
Two forced air system are deployed. The under fire forced draft and over fire and swirling draft i.e induced draft. The system is designed to supply excess air to allow for variability in fuel condition, moisture content, particle sizes and species of wood and fuel type. This is obtained by taking air (fresh or preheated) of the chimney. In this system the fuel gas is less dense than the ambient air surrounding the boiler, the denser column of ambient air forces combusted air into and through the furnace and boiler with the aid of high speed fan.

**F. Heat Furnace/Combustion chamber**
The furnace (fire box) is a chamber in which chemical energy in fuel is combusted to liberate heat energy. It also provides support and enclosure for the combusting equipment and heat exchanging water tube. The furnace wall will be made of high temperature fire bricks and refractory material, heat resistance fire concrete, bond chemical fibre cement (sugar sulphuration and calcium silicate). This material has resistance to change its shape, weight and physical properties at high temperature.

**G. Steam Generation**
The steam generators utilize the heat produce from the waste in the fire box to heat up water in the water tube type unit to produce steam. The tubes are made from block steel of 10mm thickness and 5m long. The tubes are connected to water header and steam header. The water headers the steam headers are positioned at the same level and steam level in the boiler. The boiler is a close vessel in which water under pressure is transformed into steam by application of heat. The boiler to be use in this power plant is the water tube boiler. The water is inside the tube and hot gases in combustion chamber are outside the tube. The fluid gas in fire box is blown through the boiler via the force draught fan to the chimney.

**IV. FINDING**
The total combustible waste produce in Ondo state is 376,340.3 Kg per day, this can generate 1.156Mw-h while in Edo state 360,228 Kg of waste is produce per day, this can also generate 1.107 Mw-h. This approach can be used to complement power generation in Nigeria

**V. CONCLUSION**
The waste to power generator provide an additional energy generation platform. This control combustion of waste can be considered as an effective tool for waste disposal, it also helps reduce the health treats associated to waste dump site.

**ABBREVIATIONS:**
- UP: Urban Population
- PD: Percentage Distribution
- TP: Total Population
- SUP: Sub-urban Population
- RP: Rural Population
- UW: Urban Waste
- AWG/P: Average waste generated per person
- CW: Combustible waste
- CWCF: Combustible waste considered as fuel
- SUW: Sub-urban waste
- RW: Rural Waste
- TCWG: Total combustible waste generated

**REFERENCE**