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Modeling of 1.0 MW-h Combustible Waste Fuel Steam Thermal Station: A Panacea for Rural/Off-Grid Areas' Electrification

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Abstract
The problem of energy crisis can be best handled by making a more prudent use of some of those materials viewed as wastes. This study seeks to show how conversion of this waste to fuels can help tackle some of these energy dependent problems. A model of 1.0 MW-h steam thermal station was developed that could utilize wood and palm residues, produced by saw and palm oil mills, as fuels. Ondo and Edo States in southern part of Nigeria were considered as catchalls and data obtained from Mills in these States were used for this evaluation. Estimates were made of the capacity of these residues to evaluate the viability of the study. The Model requires 3.404 tons of waste wood or 2.70 tons of palm kernel residues per hour to meet the turbine steam consumption of 3.37 kg/s. The results revealed that the project would thrive well in the two states when wood residue is considered but could only be effectively in Edo State when firing on palm residue. The viability of the research as a panacea to ameliorate problems of power outages were validated using two software, Boiler efficiency and steam turbine consumption.
Keywords: Wastes, Steam, Electricity, National Grid, Development and Wealth

1. Inroduction

Energy is required in various forms to do useful work. In form of electricity; it is a key input to economic growth as it is required for the continued improvement in the living standard of any society (Rai, 2008). Most electricity consumers in developing countries (e.g. Nigeria) are connected to the national grid which is bedeviled with high energy losses and incessant power outages. The factors responsible for these energy losses include, long transmission line (Onohaebi and Kuale, 2007), physical deterioration of the transmission and distribution facilities and inadequate metering (Omorogiwa, 2013). The resons for the outages might be due to aging of power equipment (Atakulu, 2006); shortage of power fuels which could be as a result of incessant vandalization of connected pipelines by aggrieved youth, such as the case of militants in the Niger Delta (Adenikinju, 2005; Obasi et al., 2018, Ogundele et al, 2018,); conducts of concerned stakeholders such as their personnel (Ikechukwu, 2005 Agbo, 2007 and John, 2007) or their non-renewable nature (Ogunyiola, 2011). These challenges have prevented targeted growth in the energy sector. Some of the rural communities are off the grid line, hence, they have little or no access to electricity. Off-grid, which refers to not being connected to a grid, can be stand-alone systems (SHS) or mini-grids designed, typically, to provide a smaller community with electricity. Off-grid electrification is an approach to access electricity used in countries and areas with little access to electricity due to scattered or distant population; it can be any kind of electricity generation.

Nigeria, a typical developing Nation, has twenty four (24) power generating stations; comprising four hydro-turbine station and twenty gas-turbine stations (Omorugiwa 2013) with total installed capacity of 12,544 MW, available capacity of 6,073.5 MW and load demand of 14,630 MW as at August (NIPP Daily broadcast report 5/8/2014) .is endowed with rural and urban distributions of population estimated at 150 million (Nigeria population commission 2006), but plagued with incessant power outages despite this installed capacity (Onohaebi and Kuale 2007; Omorugiwa 2013).

Today, every country draws its energy needs from a variety of sources. Energy sources, therefore, have to be explored and developed to enhance industrial progress, national security and financial stability of the Nation. (Nag, 2007). During the last century, wood was replaced as the primary fuel by coal in bulk energy production but it has not ceased to be a major source of cheap energy for domestic purposes in homes. (Rai, 2008) With the recognition of the fact that domestic inflation and related economic factors, adjustments in lifestyle and national security are highly dependent on the availability of energy supplies whose reserves are finite, there is the need to develop and improve energy availability by utilizing energy conversion strategies based on renewable energy sources such as wood waste or farm residue to generate electricity. Wood and palm oil production industries produce large volume of residues, otherwise known as waste and existence of these wastes occur in two folds: unavoidable and avoidble. Unavoidable wastes are those whose production cannot be prevented, even when the saw kerf and mills workers are efficient; these include sawdust, kernel shells, chaff, incorvertible slabs and strips whilst avoidable wastes are those produced by lack of: pre-inspection of trees and logs, inadequate production line maintenance, poor harvesting and post-harvesting techniques which result in residues in form of branches, off cuts stumps, small diameter-sized-timbers, oil-ladened-wet cake, uncrackened kernels being produced. When these unavoidable and avoidable combustible wastes generated during harvesting and post-harvesting processes are pooled together, they are enormous, and controlled burning of them for energy generation would make them to be environmental friendly and add value to material. Therefore, the concern of this study is to formulate a model of 1.0 MW-h steam thermal plant utilizing waste wood as fuel

2.0 DESIGN METHODOLOGY

2.1 Design Criteria

The following criteria were considered based on the capacity of this model, with reference to Approximate Performance Data for 1.0 MW-h Steam Power Plants (Aschmer) as reaffirmed by Nag (2011), Rajput (1997) and Chattopadhyay (2004) and Nigeria National Grid

1. air supplied is 20 % in excess
2. Air contains 21% O_2 and 79% N_2 (other inert gases inclusive) by volume and in terms of mass, it contains 23% O_2 and 77% N_2
3. Ambient temperature is 40 °C
4. Steam temperature and pressure is 300 °C and 15 bar
5. Flue Gas Temperature exiting the air-heater is 180 ^oC (as lower temperature causes acid rain formation)
6. Flue Gas Velocity is 13 m/s
7. Air Velocity is 10 m/s (as it is a high ash fuel),
8. Exhaust pressure is 1.2 bar
9. Bipolar generator with frequency of 50 Hz in-line with Nigeria National Grid
10. Exhaust conditions is near saturation
11. Stage efficiency is 62 % and reheat factor is 1.0

2.2 Model Design Fundamental

Fundamental laws of thermodynamics and heat and mass transfer together with thermal properties of the concerned materials were used in the model design to analyze the processes and units involved in carrying out this study. The study focussed on two overlapping part of the model. The first part focussed on estimating the quantity of air, fuel, water as steam required for geneating 1.0 MW-h steam power plant when wood waste (with percentage chemical composition by mass:49% C 6% H_2O; 44% O_2; 0.4% N_2 and 0.6% Ash) is used as the fuel and the second part focussed on evaluation of the design using data obtained on wood and palm oil residues to predict the workability of the model so as to know the viability of the model in ameliorating the effects of incessant power outages, most especially, in communities off the national grids.

2.2.1 Volumetric Analysis of Waste Wood at 20 % Excess Air

Table 1 shows how the volume of air required at 20 % excess was estimated whilst Tables 2 and 3 depict the determinations of the fuel calorific value and calorimetric temperature based on trial and error method.

Table 1: Volumetric Analysis of Waste Wood at 20 % Excess Air

In terms of % Weight	Mass (kg)	In terms of Mole Volume	O_2 Requirement
C = 49	12	$\frac{49}{12} = 4.083$	$C + O_2 - CO_2$ (4.083)
H_2 =6	2	$\frac{6}{2} = 3$	$H_2 + {}^1/_2\, O_2 - H_2O$ (1.5)
N_2 = 0.4	28	$\frac{0.4}{28} = 0.014$	
O_2 = 44	32	$\frac{44}{32} = 1.375$	
Ash = 0.6		$\sum O_2 =$	4.208 Mol/vol/ww
Minimum volume of air required for combustion :		$4.208 \left[\frac{100}{23}\right] = 20.040\ Nm^3$	
volume of air at 20 % required for combustion		$20.040 \times 1{,}2 = 24.048\ Nm^3$	

Hence, 1.0 kg of wood would waste require 24.048 Nm^3 at 20 % excess air

2.2.2: Determination of the wood calorific value

The calorific value refers to the heat energy released by the complete burning of unit quantity of fuel. Table 2 shows the method used in computing the caloric value of wood residues

Table 2: Calorific Value of Wood

Reactant	Reaction	Heat of combustion (kcal/kg)	Heat evolved (kcal)
C	$C + O_2 - CO_2$	(+)8137.5	$8137.5\ (\frac{49}{100}) = 3,787.$
H_2	$H_2 + \frac{1}{2}O_2 - H_2O$	(+)28905	$28905(\frac{0.5}{100}) = 144.5$
$\sum H_{comb}$			4, 131.9

Table 3: Calorimetric Temperature, (T_{wcal}) based on heat contents of gases

Flue Gas	Heat Content (kCal/kg)		Specific Weight	Heat Required (kCal)	
	1, 700 °C	1, 300°C	100(Basis)	1, 700 °C	1, 300°C
CO_2	469.070	347.159	1.7966666652	842.798366	623.729003
H_2O	933.388	660.055	0.54	504.02952	356.4297
N_2	452.321	337.536	0.93488333324	2, 133.27614	1, 827.449019
O_2	406.406	303.409	0.26933333326	109.4586813	81.73432
				3, 905.191477	2, 889.342038

Hence, At 20 %, the volume of air required for combustion of 1 kg waste wood is 24.05 Nm^3. The calorimetric temperature obtained by interpolation is 1, 675.05084 °C, whilst the calculated gross calorific value (C_{wd}) is 16.086 MJ/kg dry weight. This calorific value agreed with the findings of Rajput (1997) and Nag (2011) that the calorific value of wood ranges between 15.8 MJ/kg to 20.9 MJ/kg dry weight.

2.2.3:Determination of the turbine internal efficiency (η_{int})

Figure.1 shows the T-S diagram of 1.0 MW-h waste wood steam thermal power plant (WWSTPS) and Table 3 shows the thermodynamic conditions of steam at turbine inlet temperature

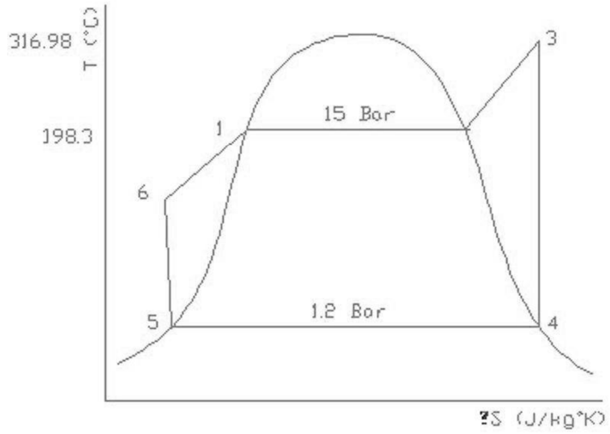

Figure 1::T-S diagram of 1.0 MW-H waste wood steam thermal power plant (WWSTPS)

Table 4: Conditios of steam at inlet turbine temperature (300 °C)

Press(bar)	v(m^3/kg)	h_f (kJ/kg)	h_{fg} (kJ/kg)	s_f (kJ/kgK)	s_{fg} (kJ/kgK)	T_{sat} (°C)
15	278.5			6.978		198.3
1.2		439.4	2244.1	1.3699	5.9375	
15 bar and 300 °C		h^* = 3037		s^* = 6.918		

Determination of the stages thermodynamic properties

The internal efficiency, according to Chattopadhyay (2004), is expressed as:

$$\eta_{int} = \frac{h^* - h_2}{h^* - h_{f2}} \quad (1)$$

Since process 1 -2 is an isentropic expanssion process:

$$, s_1 = s_2, = s_{f2} + x.s_{fg2} \text{ (Nag, 2008)} \quad (2)$$

$$\text{and, } h_2 = h_{f2} + x.h_{fg2} \text{ (Rajput, 2007)} \quad (3)$$

so that the adiabatic specific enthalpy drop (Δh) = h^* - h_2 (4)

when values substituted the dryness fraction (x) becomes 0.936, enthalpy drop Δh = 500.68kJ/kg `

2.2.4: Determination of the Workdone

Impulse steam turbine was considered because it is a single state process.Turbine and pump are the two work utilizing components involved in the eneygy generation. The turbine workdone (W_{exp}), according to Nag (2008) which is the product of the adiabatic enthalpy drop and stage internal eficicency, can be expressed as

$$W_{exp} = \Delta h. \eta_{int} \quad (5)$$

when values are sustituted, the workdone by the turbine is 315.74 kJ/kg of steam

2.2.5: Determination of Quantity of water/steam Consumption

With proposed 1.0 MW (1341hp) of power to be generated, the steam consumption can be obtained as follows: 1 horsepower-hour (hp-h) = 2685.6 kJ (by conversion) and workdone by the turbine per kg of steam is equal to the turbine enthalpy drop, therefore, the steam consumption per horsepower-hour (m_{st}), which is the ratio of the horsepower-hour to the turbine workdone, can be expressed as:

$$m_{st} = \frac{2685.6}{W_{exp}} \quad \text{(Chattopadhyay, 2004)} \quad (6)$$

whilst, steam consumption per second $(m_{st}{}^*)$

$$= \frac{rated\ proposed\ hp\ xm_{st}}{3600}$$

when value of W_{exp} is subsbstituted, the steam consumption per hph is 8.506 kg and per second is 3.17 kg. However, not all the water supplied is converted completely to steam, certain fraction of this working fliud always exist to occupy the water space. The quantity of water evaporated from and at 100 ^{o}C to produce saturated steam at this temperature by absorbing same amount of heat as used in the steam generator under actual operating conditions is known as equivalent evaporation (m_{eq}). The equivalent evaporation, according to Nag, (2008) is given by:

$$m_{eq} = \frac{m_{act}(h^* - h_{fw})}{2257} \quad \text{or } m_{act}.f \quad (7)$$

At the feedwater conditions of 151.72 ^{o}C /4.99 bar, the feedwater enthalpy (h_{fw}) is 639.72 kJ/kg, the factor of evaporation f, when values are were subsituted in equation (), is 1.022. Hence, the actual mass of water required in the boiler drum for onward production of steam is 3.37 kg/s.

2.2.6: Determination of Quantity of Fuel (waste wood) required to run the Power Plant (m_{awd})

In practice, not all the fuel (waste wood) charged into the furnace burns completely some are left behind occupying the furnace bed unburnt, assuming the percentage of this unburnt fuel is 1 % and besides, other accessories (superheater and air-heater) are also involved to obtain the steam generator eifficiency. Thus, the steam generator efficicency (η_{sg} =) can be expressed using equation proposed by Raynor (2008) as:

$$\eta_{sg} = \eta_b + \eta_{sh} + \eta_{ah} \quad (8)$$

The actual mass of charged wood burnt, $m_{awd} = m_{wd}\left[1 - \frac{1}{100}\right] = 0.99\boldsymbol{m_{wd}}$ (ton/hour)

Charged fuel energy input = $m_{awd}.(C_{wd})$ (Eastop and Mcckonkey, 2009) (9)

Boiler efficiency, η_b, which is the ratio of the heat load of the generated steam to the heat supplied by the fuel over the same period, is expreeed in equation (10) as:

$$\eta_b = \frac{h^* - h_{fw}}{C_{wd}} \quad \text{(Nag, 2008)} \quad (10)$$

which is equal to 14.9 % when values substituted.

Also, the boiler efficiency can be expressed as:

$$\eta_b = \frac{m_{act}(h^* - h_{fw})}{m_{awd}C_{wd}} \quad (11)$$

The superheater efficiency,

$$\eta_{sh} = \frac{m_{act}Cp_{st}(T_{osh} - T_{sat})}{m_{awd}C_{wd}} \quad (12)$$

and the heater efficiency

$$\eta_{ah} = \frac{m_a Cp_a(T_{oa} - T_{ai})}{m_{awd}C_{wd}} \quad (13)$$

hence, the mass of waste wood required (m_{awd}) and steam generator efficiency when values substutted are is 3.404 t/hr or 29819.4 t/yr and 34.69 %

3.0: Estimation of Quatity of wood produced based on Data collated

This study was carried out in Ondo and Edo State twenty-five sawmills were selected for the analysis out of.283 and 250 sawmills in the Ondo State and Edo state respectively. The data collected daily from each sawmill were separately analyzed. The assumptions used to estimate the volume of wood residue generated by the milling operation in each of the sampled sawmills are outline below

1.Volume of each of the logs, before conversion was carried out each day, was obtained using euqations proposed by Newton:

$$v_1 = \frac{\pi[d_b^2 + 4d_m^2 + d_s^2]L}{24} \quad (14)$$

where, V_1 = volume of log (m^3), db = diameter at the large end of log, dm = diameter at midpoint of log, ds = diameter at small end of log, L = Log length (m), $\boldsymbol{\pi}$ = 3.142 or 22/7

2.Total volume of the various dimension lumbers obtained per day from timbers in equation (14) above is obtained using:

$$\boldsymbol{v_2} = \frac{\boldsymbol{L.B.H}}{\boldsymbol{N}} \quad (15)$$

where, V_2 is the Volume of sawn lumbers (m^3), L= Length (mm), B = Breadth (mm), H = Thickness (mm), n = Total number of lumbers obtained

3 The total volume of wood waste generated per day from the conversion of timbers to lumbers is estimated using equation (16):

$$v_w = (v_1 - v_2) \quad (16)$$

Where, V_w = Volume of wood waste (m^3), V_1 = Volume of round logs before conversion (m^3), V_2 = Volume of lumbers obtained after conversion (m^3)

4.The percentage waste was therefore calculated using the formula

$$v_w{}^* = \frac{100v_w}{v_1} \quad \textbf{(17)}$$

3.1: Data collection and Analysis

Table 5 shows the names and capacities of the various Saw Mills visited in the two States in the course of gathering these data whilst Table 6 shows the estimated MW-h electrical energy that could be generated this wood waste.

Table 5: Average number of round log / lumber converted and wood waste generated per day from 25 sampled sawmill in Ondo State

S/N	Name of Saw Mill `		Average No. of Log Converted		Average No.of Lumber produced		Average Vol. of Wood Waste (m^3)		% Vol. of Wood Waste	
``	Ondo	Edo								
1	Aladekoya	Peace and Goods	23	22	217	291	5.39	7.52	43.79	42.68
2	Arometa	Iyaye	29	38	364	415	7.87	15.99	45.20	40.85
3	Okunrinboye	Beside	18	26	279	252	4.45	6.12	37.62	40.13
4	Olu	Osagba	22	20	198	315	5.98	7.41	43.62	38.73
5	Ajibolade	Mama Peace	20	14	202	211	4.24	4.57	42.48	43.61
6	Young Melo	Igede	19	20	229	214	4.05	4.93	45.81	40.61
7	Igbalaye	Solid	17	32	379	295	4.39	7.89	40.24	43.28
8	Enete	Felix	36	17	284	257	7.97	4.28	47.78	40.45
9	Ogedengbe	Madam Case	18	21	179	291	3.94	6.44	44.22	43.78
10	Monday	03-Feb	15	26	222	202	4.72	4.23	45.56	42.81
11	Agbo	G and D	22	22	341	177	7.68	4.86	41.07	45.25
12	Olukayode	Ogunwole 1	24	38	260	301	6.10	10.04	43.17	51.07
13	Olubi	Ogunwole 2	40	18	463	379	16.49	4.73	41.92	40.02
14	Tony Six	Atafo	23	20	301	184	8.06	4.84	43.15	44.20
15	Adebiyi	Jegede	32	17	326	222	7.60	4.67	44.37	41.00
16	Aruwajoye	Ohiomoba	16	29	236	263	4.94	4.89	42.15	39.28
17	Obanigba	Ikpokpoki	28	18	204	204	5.71	5.20	42.55	48.87
18	Patrick	Emeka	20	20	198	360	5.64	7.48	46.34	36.79
19	Bosun	Obarern	19	15	205	215	4.51	4.11	41.19	42.63
20	Alayamesan	Usihoro	23	24	410	355	6.12	6.32	41.30	40.20
21	Osinnuwa	Samuel	13	30	228	230	3.65	7.26	41.86	39.82
22	Landlord	Destiny	21	18	380	230	7.74	4.91	41.95	41.19
23	Owadasha	Omoh	16	29	204	196	5.10	5.82	47.57	43.63
24	Aramco	Adegan	28	22	290	208	5.50	5.53	41.01	41.67
25	Bukola	Osarieme	16	20	215	201	3.68	4.23	35.76	38.07
26	Asis	Odia	22	30	162	295	5.19	5.57	45.49	41.35
27	Ajayi	Odeh	17	18	218	186	7.02	3.87	43.31	43.83
28	Ogun	Erabor	18	27	316	231	8.63	6.32	41.19	42.30
29	Williams	Andy	16	25	202	188	5.46	5.46	43.23	44.10
30	Ema	Lady	27	23	213	239	6.23	5.03	44.31	42.55
31	I need Money	Udekwe	19	20	301	153	6.72	4.39	41.61	41.61
32	Means	Orow	18	18	178	358	4.34	7.14	40.11	42.83
33	Oyo	Nosa	20	11	322	129	7.41	4.36	44.29	45.32
34	Jacob .J.	Aburimen	10	19	190	249	3.50	4.94	41.42	42.19
35	Agbebi	Teacher	12	15	227	216	4.12	5.27	43.10	41.30
36	Afe	Xt	13	22	188	220	4.32	4.47	39.60	43.61
37	LK	Osun Nig Ltd	11	29	213	197	4.07	5.28	40.22	44.30
38	Bosun	Abusonwen	14	18	256	228	5.13	4.19	42.40	42.20
39	Akin Elemo	Serena	11	10	192	256	4.30	3.91	46.69	45.20

40	Oluwatuyi	Price	13	26	248	299	4.08	5.20	41.80	47.53
41	Oluwatoyin	Onyeka	10	19	273	308	3.82	7.22	39.59	44.51
42	Emeka	Friday Ogbome	20	17	289	168	5.07	8.05	40.21	43.12
43	Otunba	Solid	18	28	211	158	5.18	6.81	43.13	45.19
44	Busuyi	DE Mercy	20	14	316	192	6.24	5.01	40.49	43.72
45	Tunji	Alohan	12	13	190	217	4.26	3.69	39.41	46.47
46	Niyi	Idiode	11	19	218	206	4.15	4.42	40.29	42.30
47	Microfeed	Charles	13	21	215	215	4.84	5.32	42.79	45.98
48	Niyi	Sunny Ogbomo	11	17	188	201	5.23	4.21	41.91	41.68
49	Odunayo	Madam Chichi	16	21	192	188	4.49	5.33	40.31	43.19
50	Major	Omosegho	20	25	222	216	5.36	6.11	39.21	44.60
Sum			950	1091	12554	11981	280.68	285,84	2117.77	2141.64
Mean			19	21.62	251.08	239.62	5.61	5.72	42.36	42.83

Source: Extracts from feasibility studies conducted through participant observation, 2012

Table 6: Estimated MW-h energy generation from waste wood

	Ondo	**Edo**
Average volume of log converted per day (cm^3)	**14.13**	**14.735**
Average number of lumber converted per day	**27.2**	**258.72**
Average volume (in percentage) of wood waste generate (m^3)	**46.69**	**1536**
The Estimated volume of wood waste generated (m^3)	**629,686.32**	**560,640**
Mass of wood produced per year (t/yr)	**421,889,833.40**	375.628800.00
Probable MW-h generated with the available wood per year	**3.55**	3.16

3.2: Evaluation Procedure of Oil Palm Residue

In other to evaluate the oil palm residue available in Ondo and Edo State, field and source data from the Ministry of Agriculture and Natural resources, Nigeria Institute for Oil Palm research (NIFOR), Presco Plc, Nifor, Iyare Oil, Okada Wonderland, Okomu Oil, in Edo State and Okitipupa, Investment Holdings (Ararormi and Irele), and Ore Irele Oil Palm in Ondo State were obtained on the estimated area under oil palm in different production system. These Mills were classed under three headings, based on their capacities, as; (i) estate plantation, (ii) medium / small holding, and (iii) wild groove. In the course of estimating the viability of this model with preference to the quantity of palm kernel residues generated, the caloric value of palm kernel was considered as 18,828 kJ/kg based on findings of Ugwu and Agbo (2011). Thus, for I Joule of energy generated with waste wood, Palm kernel would generate 1.174 Joules with the same mass

Table 7: Estimated palm kernel residues Production Capacities

	Ondo		Edo	
	Land area (Hectare)	capacity	Land area (Hectare)	capacity
Medium (5t/hec)	10,143	50,715	24 542	122, 710
Wild groove (1.5 t/hec)	83,000	124,500	50,000	75, 000
Estate (5t/hec)	26,262	131310	36,478	182, 390
Combustible residue (30 %)		91,957.5		114, 030

Table 8: Estimated MW-h energy generation from selected Waste wood and Palm kernel residues in Ondo and Edo States

Fuel Type	**Caloric value (kJ/kg)`**	**Mass of Fuel (ton/yr)**		**Estimated MW-h generated**	
		Ondo	Edo	Ondo	Edo
Wood residue	16,086	421, 889.8344	375, 528, 800.00	3.55	3.16
Palm kernel residue	18884	92,957.5	114,030	0.92	1.00

3.3 Validation of Results

The validation of the results of this study was done using two sofware boiler efficiency (otherwise called Kane International Engineering Calculator) and steam turbine consumption calculator , (sugar engineering library/

Karmar software) and the comparisons between the calculated and software results are as detailed below (Table 9)

Table 9: Comparison between Calculated and Software Results

	Steaam Generator efficiency (%)	Turbine steam consumption (kg/s)
Software	38.72	3.228
Calculated	35.69	3.17

4.0: Results and Discussion

The estimated calorific values of wood and palm kennel residues are 160868 kJ/kg and 188880 kJ/kg. The quantities of wood residues generated in Ondo and Edo States are 471, 889, 8344 tons/year; Each of these quantities is capable of running a Unit of 1.0 MW Power Plant for 3 year or 3 Units of 1.0 MW for a year..Also, the Palm kernel residues generated in Ondo and Edo States are 92, 707.5 and 114,626 tons/year. This quantity of fuel is capable of running 0.95 MW Power Plant for a year in Ondo and 1.0 MW electrical Power Plant for a year in Edo. Hence, the usage of wood waste as fuel is viable in both states but a similar Unit running on palm residues is only viable in Edo State.

5.0: Conclusion

A Model 1.0 MW steam Thermal Power Plant was developed and the results of the Model were compared with results obtained from boiler efficiency and steam turbine consumption calcualtors to confirm its workability. The Model, which can be fired with either waste wood or palm kernel residues, requires 3.404 tons of waste wood or 2.70 tons of palm kernel residues per hour to meet the turbine steam consumption.

The Model, if harnessed, would ameliorate problem of incesant power outages, help converting waste to wealth, eliminate the need to use valuable land for landfills, minimize spread of diseases and can be incorporated in industries where co-energy process of steam and electrical energy is needed.

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