Original Research Article

Exploitation of Empty Palm Fruit Bunch for the Generation of Electricity

.

ABSTRACT

This aim of this study is to evaluate the utilization of empty palm fruit bunch for the generation of electricity. The empty palm bunch was used in firing a steam turbine plant (boiler) for the generation of electricity. The power plant that was used in this research is owned by PRESCO Nigeria Limited located in Ikpoba-Okha local government area of Edo state. 1.7 MW of electricity was generated by burning empty fruit bunch (EFB) at a rate of 896 kg per hr. This value was compared with the traditional power plant fired by methane gas which produces 4.5MW. The cost of producing power using methane gas is very expensive estimated to about 2500 dollars compared to the cost of using EFB since it is a waste from oil palm plantation companies and abundant in nature. The use of EFB is very economical as an alternatives fuel in firing a boiler plant and elimination of wastes from the plant.

Keywords: Palm fruit bunch, Waste conversion, Power generation, Renewable energy

1. INTRODUCTION

Energy is a social and economic need of any country. The energy use in any country is expected to continue to increase as its population increases [1]. Nigeria's population has increased from 159 million in 2010 to about 187 million in 2016, which will demand about 25000 MW for homes and industries in other to have stable electricity. Electricity is essential for the economic growth and improvement of the standard of living of the increasing population. Therefore without adequate basic energy supply, people will not be able to meet up to their domestics needs such as cooking, light their home and chilled up their perishable goods and other needs that require electricity [2].

The demand for energy is increasing globally especially in Nigeria, which the chief source of power generation is hydro, steam and gas turbine. A lot of research activity has been done in Nigeria and some are still going on how to find a solution to this power problem in the country in other to find substitutes to fossil energy [3]. These alternatives are intended to address concerns about the exhaustion of fossil fuel because they cannot be used forever.

Oil palm (*Elaesis guineensis*) is one of the most important economic oil crops in Nigeria. According to the *World Rainforest Movement* (WRM), oil is indigenous to the Nigerian coastal areas [4]. An oil palm plantation produces enormous volumes of wastes such as empty fruit bunches (EFB), palm kernel shell (PKS) and palm oil mill effluent (POME). Empty palm bunch contains neither chemical nor mineral additives; it is free from foreign materials depending on handling operations at the mill. Pre-processing of EFB is essential before it can be measured as a high-grade fuel since the moisture content is approximately 70%. This material is very cheap for the generation of electricity due to its high availability compared to the conventional system (hydro and gas turbine) which is very expensive. It is very eco-friendly compared to the general flaring of gas which is the major source of global warming.

Nigeria generates a considerable quantity of agro-waste. This will present great prospects for exploiting biomass energy in an eco-friendly and commercially viable manner. EFB can be transformed into renewable energy resources that could meet the needs of industries and the national grid. To achieve this, pre-treatment steps such as shredding and dewatering are required in order to improve the fuel property of the empty palm bunch. In fact, palm oil mill (POM) using a cogeneration system for producing steam and electricity demands using one source of fuel in the milling process. The cogeneration system consists of a boiler, turbine, and generator. Fiber and shell are burnt directly in the boiler to form superheated steam (fiber 65:35). Half of the steam is used for milling processes. Residual steam is converted to electricity using a turbine. Fiber, shell and empty palm bunch are useful for the heating purpose because of its calorific value.

Palm oil is currently the world largest source of edible oil. Palm oil mill in Nigeria produces about 0.94 million tones and 1.54% of world total oil produced in 2015. It is predicted that the demand of world palm will remain of high increase as followed by the population growth, food, and industrialization. The more crude palm oil (CPO) produced the more biomass wastes. A palm oil mill (PMO) wastes is around 13-17 % fiber, 6–10 % shell and 25-27% empty fruit bunch (EFB) based on its capacity. However, this biomass waste is needed to be utilized effectively to overcome the problem. These waste can be converted into energy using incineration or other chemical processes. Palm biomass has been long identified and utilized as renewable energy but there is rare energy power plant applied. Due to its heating value, it can be used as fuel for electricity production. According to the global market, the price of petroleum is increasing steadily. As a result industrial sectors are searching for alternative means for generating their electricity to replace the petroleum fuel in other to reduce cost. Indonesia and Malaysia, which is the world's largest palm oil producing countries generate 53.6% and 36.8% of total world oil production with about 33.4 and 19.9 million tons per annum of crude palm oil, respectively. These have assisted in changing the economy of these countries drastically. They generate electricity from the waste biomass of empty palm bunch in addition to other products. One of the unique aspects of Malaysian renewable energy sources is that the palm oil mill is self-sufficient in energy using palm press fiber (PPE), empty fruits bunch (EFB), and shell as fuels to generate steam in waste fuel boilers for processing and power generation with steam turbines [5]. This delivery electricity concept can be applied to support electricity demand in Nigeria using the national grid line as the distributing system. Also, some companies in Nigeria such as NIFOR (Nigeria Institute for oil palm oil research) located in Ovia South East and PRESCO Palm Oil Industry located in Ikpoba-Okha Local Government, Edo State Nigeria depend on empty palm fruit bunch for electricity generation, which has saved them from the problem of power interruption and cost. This empty palm fruits bunch is in abundance.

Oil palm biomass wastes emerge as a potentially major contribution to renewable energy as the government has now shifted from conventional sources such as coal, oil, and gas to promoting renewable energy sources in order to increase energy security. Indeed the combustion of fossil fuels' as sources of energy for heat, transportation, and electricity is known to be the major factor contributing to global warming. The world is moving from the conventional non-renewable energy sources to renewable energy sources due to their renewability and eco-friendly nature, which is critical for the future generation of power. The Malaysian government has made several efforts to encourage the use of renewable energy to scale down dependency on fossil fuels and to meet the growing demand for energy. As a result, the Fifth Fuel Policy was introduced in 2001 to encourage new renewable energy sources such as oil palm, rice husk, and wood waste to compliment the conventional energy supply [6]. The adoption of this fifth-fuel policy was supported by the implementation of the small renewable energy power (SREP) [7]. Sarawak, one of the largest town in Malaysia has the potential to generate a total of 425 MW of electricity from biomass sources, where 375 MW of this amount was contributed by palm biomass. In Nigeria, most of the electricity generated is from gas fire thermal power plant which uses several methods in its conversion. One of the methods is burning the gas in a boiler to produce steam, which is then used by a steam turbine to generate electricity. Thus, this has led to the over-dependence on the conventional oil; this has led to gas flaring, which can be converted to more meaningful products instead of wasting the resources. Over-dependence on hydropower and steam turbine in Nigeria has made this biomass to be underutilized. Considerable research and development are currently ongoing to develop smaller gas fires that would produce electricity on a small scale. Currently, biomass is used for off-grid electricity generation but almost exclusively on a large industrial scale [8].

Lignocelluloses biomass wastes produced from oil palm industries include palm kernels cakes (PKC), palm kernel shells (PKS), empty fruit bunch (EFB), oil palm tusk (OPT), oil palm fronds (OPF), palm press fibers (PPF) and palm oil mill effluent (POME). Oil palm waste is a reliable resource because of its availability, continuity, and capacity for renewable energy solution. Furthermore, the presence of oil palm waste has created a major disposal problem, thus has a negative effect on the environment. Therefore to avoid this negative effect on the environment this work will address this issue *by EXPLOITING THIS PALM BIOMASS IN GENERATING ELECTRICITY*. Apart from power generation, the fresh palm fruits (FPF) will also yield other products which will boost the economy and gross domestic product (GDP) of the country and create jobs. The increase in the population brings about an increase in the demand for electricity. Since the demand is high, the conventional source of generating electricity has not been able to meet the demands of the increasing population. The shortage of electricity has severely hampered the development of Nigeria, therefore to lessen the problem of power failure and the huge cost of using petroleum for generating power in industries, an alternative has been investigated.

The aim of this work is to evaluate the exploitation of empty palm fruit bunch as renewable energy for electricity generation. The empty palm bunch was used for firing the steam turbine (boiler) for the generation of electricity. The calorific value and the heat intensity was also determined.

2. MATERIAL AND METHODS

2.1 Materials Collection

120 tons of fresh fruit bunch was obtained from the oil palm plantation of PRESCO Nigeria Limited located at Obaretin Estate, Ikpoba-Okha local government area, Edo state, which generates 60 tons of fresh fruit bunches/hour. The fresh fruit bunch was further processed in other to get the desired raw material, which was used to fire the boiler. The Fig. 1 shows the fresh and empty fruit bunch. The empty fruit bunch are fibrous materials and the moisture content is low compared to the other biomass residues. It contains residue of palm oil which gives it a high heating value than any other average lignocelluloses biomass.

The palm press fiber and palm kernel shells that were generated in the palm oil mill (POM) were used as a solid fuel for steam boilers. The heat in the steam boilers was used in addition to empty fruits bunch (EFB) to run the steam turbine for generating the electricity. A careful breakdown was carried out in the course of this research in a well-established palm oil mill like PRESCO Nigeria. It is expected that every 100 tons of palm fresh fruit processed yields 20-24 tons of crude palm oil, 19-21 tons of empty fruits bunch, 15 tons of oil-rich fiber, 5 tons of shells, 3 tons of palm kernels, 16% moisture content and 20% effluent. The potential of biomass wastes of oil palm plantation is shown in Fig. 2.

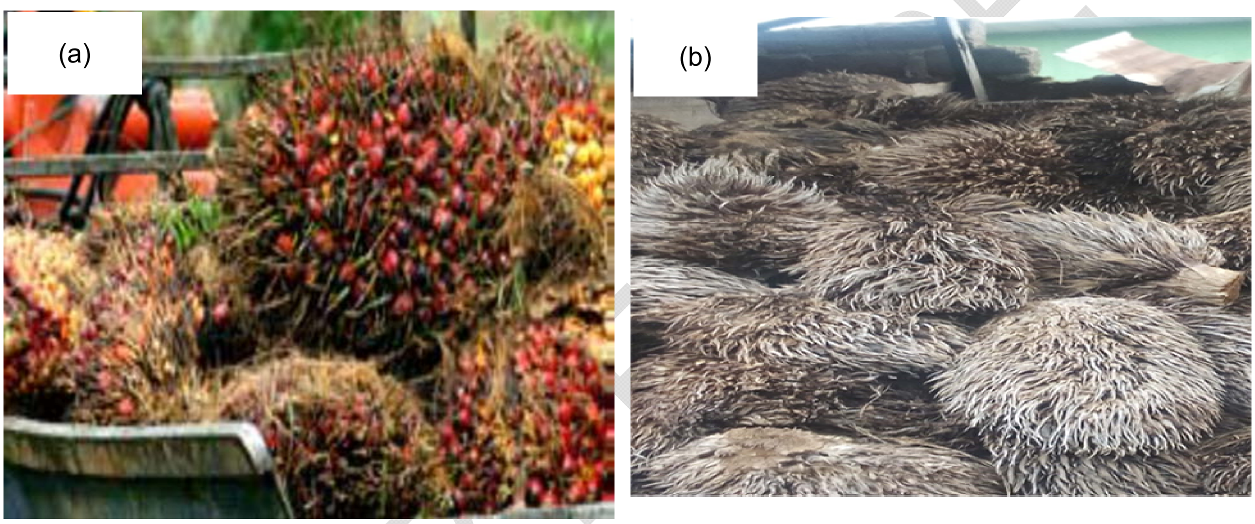

Fig 1. Fresh fruit bunch and empty fruit bunch.

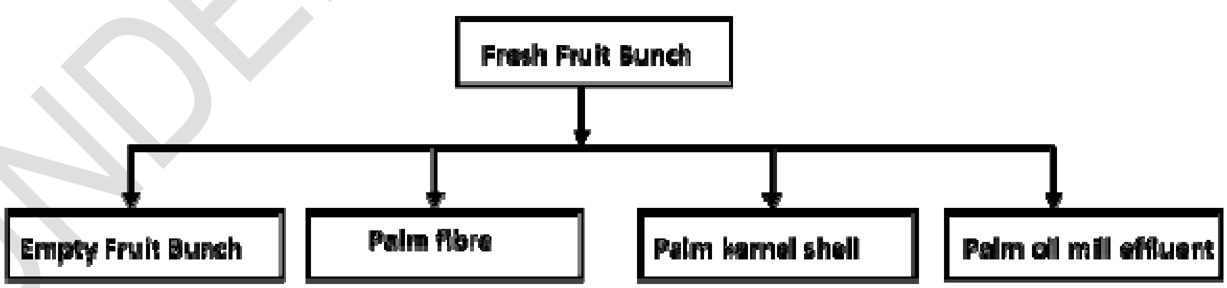

Fig. 2. Diagrammatic presentation of biomass/waste potential from oil palm plantation.

2.2 Pretreatment of Empty Palm Fruit Bunch

Pretreatment of empty palm fruit bunch is very important in order to increase its digestibility and its degree of conversion. The method of pretreatment that was used in this study is the chemical pretreatment, which involves diluting acid hydrolysis and alkaline pretreatment. Ammonia (NH4) and hydrogen peroxide (H_2O_2) solutions were used to increase the digestibility of the EFB. Fast pyrolysis with alkaline solutions (NaOH and $Ca(OH)_2$ was done followed by the addition of H_2O_2. Alkaline pretreatment has been proved by researchers to be the best [9, 10, 11, 12]. The effectiveness of alkali pretreatment might be attributed to its capability in lignin degradation.

2.3 Conversion Process

The conversion process used for this research work was the thermochemical conversion. Thermo-chemical conversion of biomass (EFB) involves heating the biomass in the absence of O_2 to yield a mixture of gas, liquid and solid [12]; the products were used as fuels after further conversion. Generally, lower reaction time (a few seconds or minutes) is required for thermochemical processes. These generally include biomass pyrolysis, gasification, and torrefaction [12].

2.3.1 EFB pyrolysis

Pyrolysis is the thermal degradation of biomass materials in the absence of oxygen [13]. It can be performed at a moderate temperature (400 – 600°C) at a short period of time. Products of pyrolysis may comprise gases (methane, hydrogen, carbon monoxide, and carbon dioxide), liquids (water, and oil/tars) and solids (charcoal). The efficiency of pyrolysis and the fractions of gas, liquid, and solid produced basically depend on the process factors such as pretreatment condition, temperature, time of retention and reactor type [12]. Misson et al. [11] observed that NaOH and $Ca(OH)_2$ couldn't modify the composition of the lignin significantly. In addition, the pretreated EFB was catalytically pyrolyzed more efficiently than the untreated EFB samples under the same conditions. Sulaiman and Abdullah [14] also observed that gas production was more favorable at higher temperatures, and the moisture content was nearly constant in the range of temperatures examined using bench top fluidized bed reactor with a nominal capacity of 150 g/L.

2.3.2 EFB Gasification

The gasification process is an extension of the pyrolysis process except that it is piloted at an elevated temperature (800–1300 °C), which implies that it is more favorable for gas production [12]. The gas stream is largely composed of hydrogen, methane, carbon dioxide and carbon monoxide. Biomass gasification presents numerous advantages including decreased CO_2 emissions, accurate combustion control, compact equipment requirements with a relatively small footprint, and high thermal efficiency [14]. The key challenge in gasification is allowing the pyrolysis and gas reforming reactions to occur using a minimum amount of energy; therefore, gasifier design is important. An entrained-flow gasifier for the gasification of EFB at 900°C was used by Ogi et al. [15]. The rate of gasification was enhanced (>99%) when O_2 was added to H_2O_2 than using H_2O_2 alone. Gasification was suggested as the most appropriate thermo-chemical route for EFB conversion to biofuels [12]. Process flow diagram of EFB gasification unit is shown in Fig 3 [12].

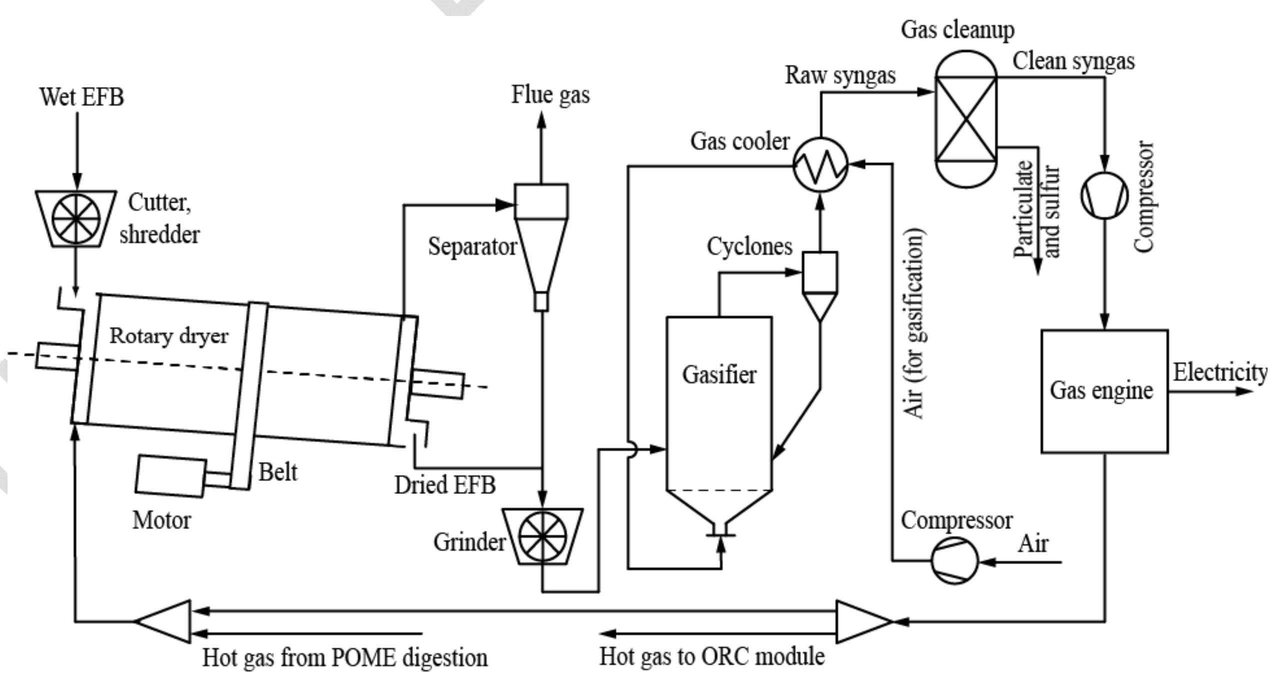

Fig 3. Process flow diagram of EFB gasification unit.

2.3.3 EFB Torrefaction

Torrefaction is a thermal conversion of biomass at the low-temperature (200-300 °C) [16]. Biomass is pretreated to produce a high-quality solid biofuel that can be employed for gasification and combustion. It is centered on the removal of O_2 from biomass to yield a fuel with improved energy density. Several reaction conditions (inert gas, temperature, and reaction time) and biomass resources lead to differences in gaseous, liquid, and solid products. Uemura et al. [17] examined the influence of torrefaction on the basic properties of EFB, mesocarp fiber and kernel shells as a possible source of solid fuel. The mesocarp fiber and kernel shell exhibited excellent energy yield with values higher than 95% while EFB exhibited a poor yield of 56%. Torrefaction can also be achieved in the presence of oxygen [18]. Fig. 4 presents the pretreatment and the conversion process for palm empty fruit bunch [12].

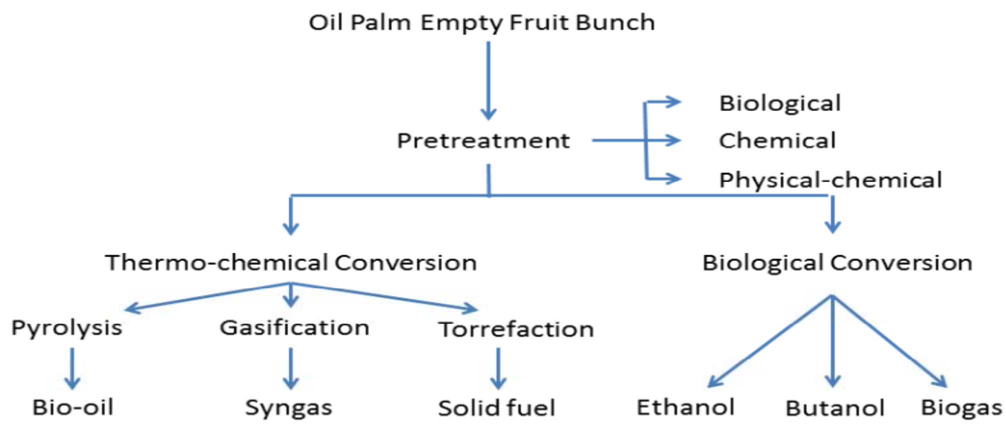

Fig. 4. The pretreatment and the conversion process for Palm Empty Fruit Bunch.

2.4 Equipment

The boiler used in this work is the PRESCO Nigeria steam boiler. It has a capacity of 25bar and was used in burning 896kg of EFB per hour, which generated 1.7 MW of electricity when compared with the combustion of methane gas, which will produce 4.58 MW of electricity. The boiler produced the required heat energy for generating the electricity. The heat generated with the boiler using 896kg of EFB has a calorific value of 19500 kJ/kg. The chimney was used in order to allow smooth flow of heat generated by the boiler to effectively power the turbine without loss to the surrounding. It is 200m tall with a diameter of 3.3 m.

The steam turbine used in this work was PRESCO Nigeria limited plant located in Ikpo-Okha Local Government Area of Edo State. It has the capacity of generating up to 1.99 MW of electricity. But for the case of this work, 1.7MW was generated when a fuel (EFB) of 896 kg was combusted per hour.

2.5 Generation Process

The technology used for this project is the steam turbine. It involves some stages of conversion; it extracts thermal energy (heat) from the fuel (EFB) in the combustion chamber via the steam boiler to raise the steam, converting the heat energy generated into kinetic energy in the steam turbine and finally using a rotary generator to convert the turbine mechanical energy into electrical energy. Fig. 5 shows the electricity generation plant using EFB. The three stages of energy conversion are illustrated below

Heat energy (steam boiler) ⟶ Mechanical energy (steam turbine) ⟶ Electrical energy (Generator)

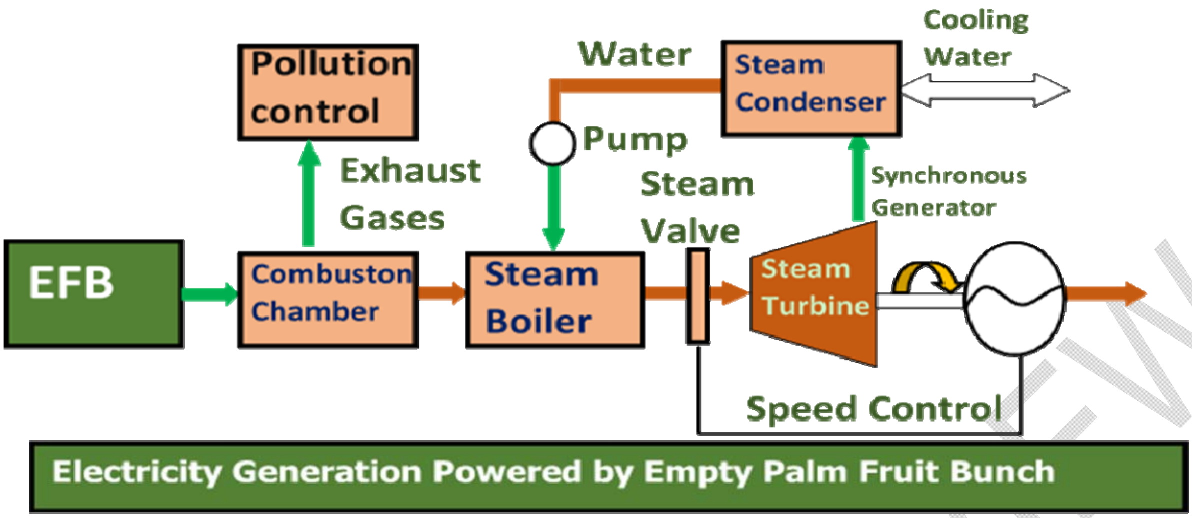

Fig. 5. Electricity generation plant using EFB.

To achieve this successfully, the moisture content of the fuel was totally reduced in order to increase the quality of heat needed to power the steam turbine.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Empty Fruits Bunch (EFB)

Empty fruit bunch possesses its own properties like the other sources of fuel. The proximate and ultimate analysis was done on the EFB to ascertain its properties. The properties of EFB are presented in Table 1.

Table 1. Properties of EFB

	Value	Unit
Components		
Cellulose	58.3	%(w/t)
Hemicelluloses	23.4	%(w/t)
Lignin	19.2	%(w/t)
Proximity Analysis		
Moisture	9.36	%(w/t)
Volatile	78.59	%(w/t)
Ash	5.31	%(w/t)
Fixed carbon	15.42	%(w/t)
Ultimate Analysis		
Carbon	46.2	%(w/t)
Hydrogen	6.4	%(w/t)
Oxygen	44.39	%(w/t)
Nitrogen	0.66	%(w/t)
Sulphur	0.08	%(w/t)
Other Properties		
Low heating value	13200	kJ/kg
High heating value	19500	kJ/kg
Bulk Density	113.92	kg/m^3

3.2 Chemical Formula of Empty Fruit Bunch (EFB)

The chemical formula for EFB was derived in this study. The formula of EFB Fuel sample is given as:

$C_zH_yO_rN_vS_m$ (1)

If Eq. 1 is on the basis of 95kg sample of EFB, the composition by mass is given as (according to Table 1):

C: 12a = 0.462, a = 0.462/12 = 0.039; H: 1y = 0.064, y = 0.064; O: 16r = 0.4439, r = 0.028; N: 14v = 0.0066, v = 0.00047; S: 32m= 0.0008 m = 0.000025.

Substituting these values of a, y, r, v and m yields Eq. 2, which is the formula of the fuel sample.

$$C_{0.039}H_{0.064}O_{0.28}N_{0.00047}S_{0.000025} \quad (2)$$

The amount of heat liberated by the rate of feeding into the combustion chamber through the furnace was also evaluated. The empty palm fruits undergo a shredding process by cutting the EFB into smaller pieces to lose its structure, this help to improve the volume weight ratio and enhance the fuel characteristic. Fig. 6 illustrates the schematic diagram of the steam turbine [18].

The combustion ratio (CR) and heat released, Q were calculated below using Eqs. 3 and 4 [18], respectively. Eq. 3 was used to calculate the combustion rate by burning 896kg of EFB per hour which gives the rate of feeding per hour.

$$CR = \frac{Total\ mass\ of\ \ burnt\ fuel}{Burning\ Time} \quad (3)$$

$$= \frac{896}{1\ hr} = 896\ kg/hr$$

$$Q = \ calorific\ value\ \times\ combustion\ rate \quad (4)$$

= 19500 x 896 = 17472000 kJ = 17.47 GJ

The average feeding per hour of operation and heat released were obtained as 896 kg and 17.47 GJ, respectively.

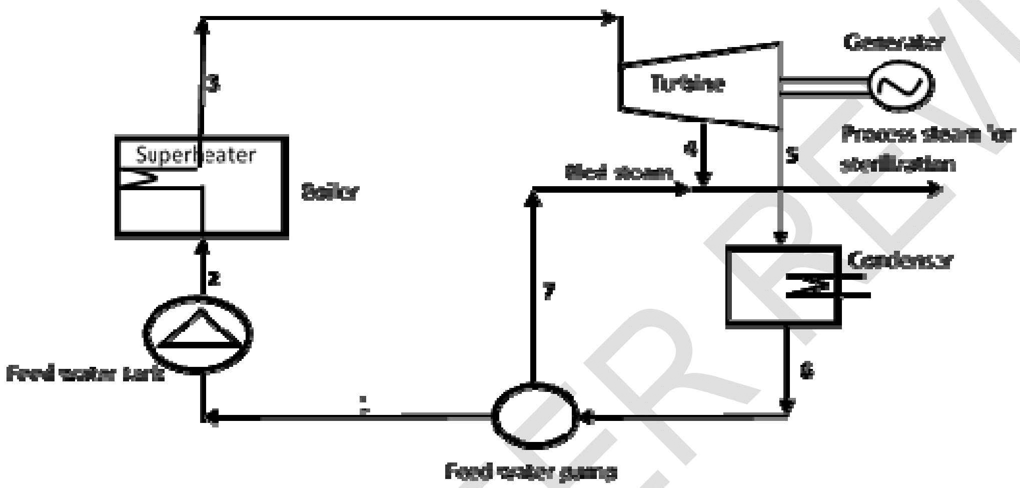

Fig. 6. Schematic diagram of the steam boiler.

3.3 Combustion of Empty Palm Fruit Bunch

The combustion of EFB in the boiler taking the calorific value, its ash content, fuel size, and moisture content into account. Complete combustion of EFB will produce water vapor (H_2O), carbon dioxide (CO_2) and other products. The combustion of EFB is explained by Eq. 5:

$$C_{0.039}H_{0.064}O_{0.028}N_{0.00047}S_{0.000025} + YO_2 + Y(79/21)N_2 \longrightarrow pCO_2 + qH_20 + tSO_2 + uN_2 \quad (5)$$

C: 0.039=p, p=0.039; H: 0.064=2q, q= 0.064/2=0.032; S: 0.000028=t, t=0.000025

0.028+2y = 2p + q + 2t

2y = 2p + q + 2t - 0.028

y = 2y = 2(0.039) + 0.032 + 2(0.000025) - 0.028

y = (0.011005-0.028)/2 = 0.041

N: 0.00047 + 2y(79/21) = 2u

$$u = \frac{0.00047 + 0.387}{2} = 0.194$$

Therefore, the balanced equation is given as

$$C_{0.039}H_{0.064}O_{0.028}N_{0.00047}S_{0.000025} + 0.041O_2 + 0.041(\tfrac{79}{21})N_2 \longrightarrow 0.039CO_2 + 0.032H_2O + 0.000025SO_2 + 0.194N_2 + Energy \quad (6)$$

Eq. 6 shows the complete combustion of EFB. Water vapor, carbon dioxide and other products were obtained. If the EFB is completely dry, the moisture content is reduced.

3.4 Power Generated by the Empty Fruit Bunch

The power produced by burning 896 kg of empty fruit bunch is given below by putting the following parameters into consideration:

Calorific value (CV) =19500 kJ/kg
Combustion efficiency (ηcombustion) = 95%
Mass of fuel (EFB) = 896 kg
Cycle efficiency (ηcircle) = 45%η
Turbine efficiency (ηturbine) = 90%
Boiler heat transfer efficiency (ηheat transfer) = 90%

The power generated was calculated using Eq. 7 [19]:

$$\text{Power} = \frac{\text{m x Cv x ηturbine x ηcombustion xη circl x ηheat transfer}}{3600} \qquad (7)$$

$$\text{Power} = \frac{896 \times 19500 \times 0.9 \times 0.95 \times 0.45 \times 0.9}{3600} = 1680.588 \text{ kW} = 1.7 \text{ MW}$$

3.5. Comparison between Empty Fruit Bunch Power Generated and the Conventional Gas Fired Boiler using Methane Gas of Same Mass of Fuel

Combustion of methane gas is given as [18]:

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O + \text{Energy} \qquad (8)$$

Heat released by methane gas is given as:

$$\text{Heat released, Q} = \text{calorific value} \times \text{combustion rate} \qquad (9)$$

Where Calorific value of methane gas = 55178.2kJ/kg, Mass of methane gas = 896kg

$$Q = 55178.2 \times 896 = 49439667.2\text{kJ} = 49.43\text{GJ}$$

Power produced from burning 896kg of methane gas is calculated using Eq. 6 when the same parameters for EFB were considered.

Where Calorific value (Cv) = 53178.2kJ/kg, Combustion efficiency (ηcombustion) = 95%, Mass of fuel (methane) = 896kg, Cycle efficiency (ηcircle) = 45%, Turbine efficiency ($\eta_{turbine}$) = 90%, Boiler heat transfer efficiency (ηheat transfer) =90%

$$\text{Power} = \frac{\text{m x Cv x } \eta_{\text{turbine}} \text{ x ηcombustion x ηcycle x ηheat transfer}}{3600} \qquad (10)$$

$$\text{Power} = \frac{896 \text{ x } 53178.2\text{x}0.9\text{x}0.95\text{x}0.45\text{x}0.9}{3600} = 4583.109kW = 4.58MW$$

3.6. Calorific Value of Fuel from EFB

The various calorific value of various fuels, which was used in firing steam boiler from the palm oil mill is shown in Table 2 and Fig. 7. All the fuels can generate good heat for firing steam boiler but EFB has the highest calorific value, therefore, it is more favorable for this work. The calorific value of 19500 kg/kJ was produced when 896 kg of EFB was used in firing the steam boiler to get 1.7 MW of electricity. This value obtained is slightly higher than the results obtained by Olisa and Kontingo [18]. The authors obtained 1.5 MW by using 840 kg of EFB in firing a steam boiler.

The moisture content of the fuel types was considered (Table 3 and Fig. 8). The moisture content was calculated using Eq. 11:

$$Y_w = \frac{M_1 - M_2}{M_1} \times 100 \qquad (11)$$

Where Y_w is the moisture content, M_1 is the initial mass of fuel and M_2 is the final mass of fuel after drying.
It was observed that the empty palm fruit bunch has the highest percentage moisture. To ensure proper heating value, it was first dried up and a superheater was incorporated in the boiler in order to increase the heating rate.

Power generated by the different mass of EFB fuel is presented in Table 4 and Fig. 9. The power generated by the different mass of methane is also presented in Table 5 and Fig. 10.
The types of fuels were also compared as seen in Table 6 and Fig. 11. The results revealed that EFB can produce about 36.6% of what the methane gas can produce giving the same amount of fuel. For the power plant using methane gas, it will cost more compared to the plant using EFB that may cost very little due to its availability especially to a country like Nigeria.

Table 2. The calorific value of various fuels.

Fuel	Calorific value(kJ/kg)
Empty fruit bunch	19500

Palm kernel shell	16200
Palm fiber	11500

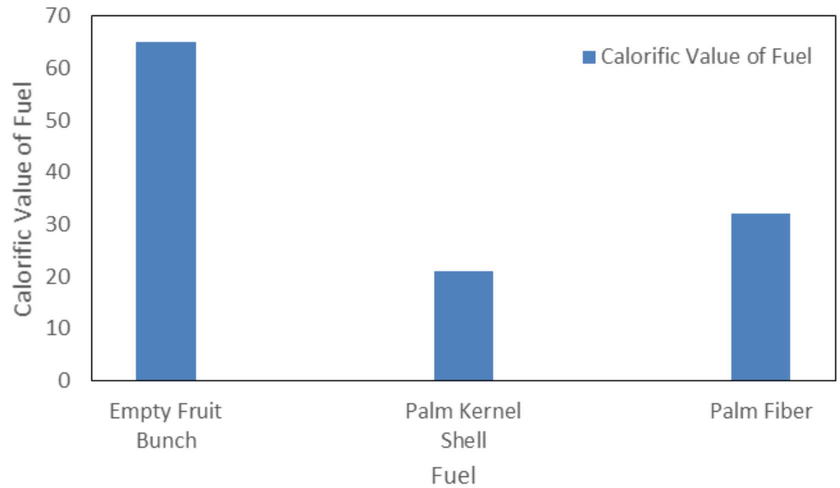

Fig. 7. Graph of the calorific value of the fuel types.

Table 3. The moisture content of the types of fuel.

Fuel	Moisture content (%)
Empty fruit bunch	65
Palm fiber	32
Palm kernel shell	21

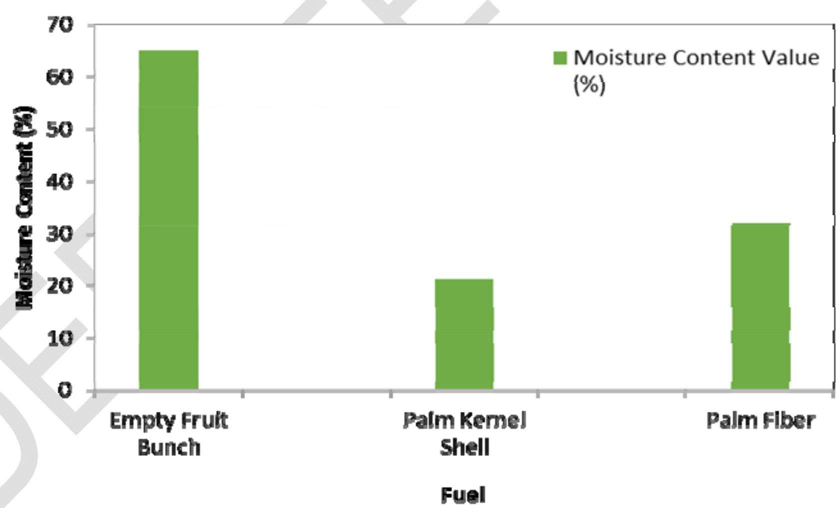

Fig. 8. Moisture content of the types of fuel.

Table 4. Power generated by the different mass of fuel (EFB).

Mass of fuel (EFB) in kg	Power generated (kW)
100	187.565
200	375.13
300	562.7
400	750.26
500	937.83
600	1125.4
700	1312.9
800	1500.52
900	1688.1

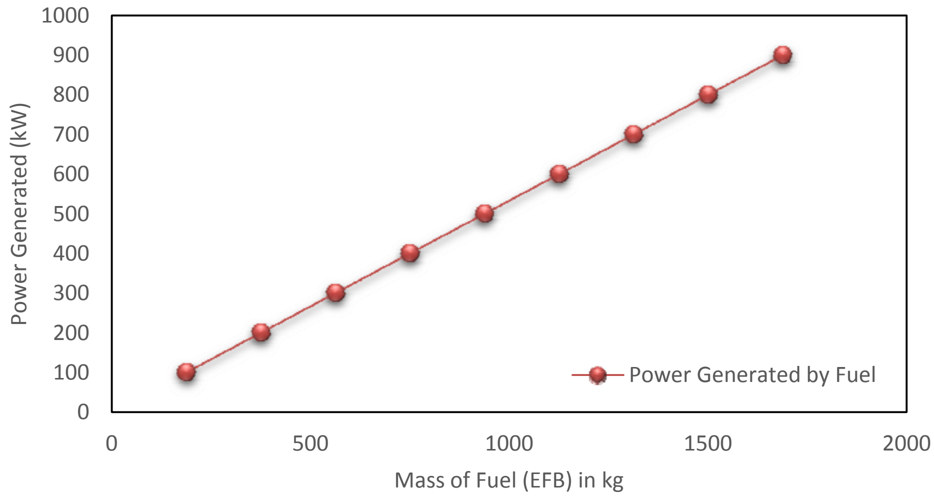

Fig. 9. Power generated by the different mass of EFB.

Table 5. Power generated by methane

Mass of methane (kg)	Power generated (kW)
100	511.507
200	1023.015
300	1534.523
400	2046.03
500	2557.54
600	3069.046
700	3580.6
800	4092.06
900	4603.6

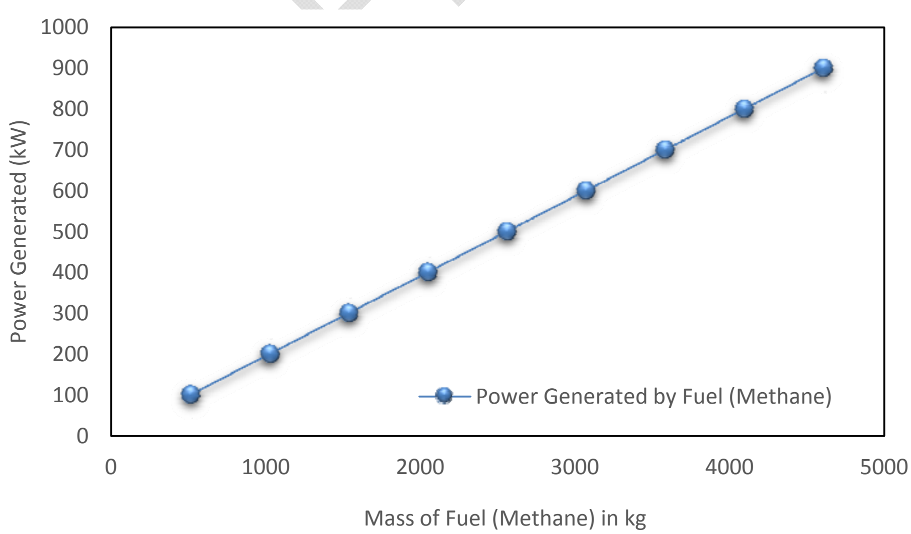

Fig. 10. Power generated by the different mass of methane.

Table 6. Comparison between the fuel types.

Mass of methane (kg)	Power generated (kW)	Mass of EFB (kg)	Power (kW)
100	511.507	100	187.565
200	1023.015	200	375.13
300	1534.523	300	562.7
400	2046.03	400	750.26
500	2557.54	500	937.83
600	3069.046	600	1125.4

700	3580.6	700	1312.9
800	4092.06	800	1500.52
900	4603.6	900	1688.1

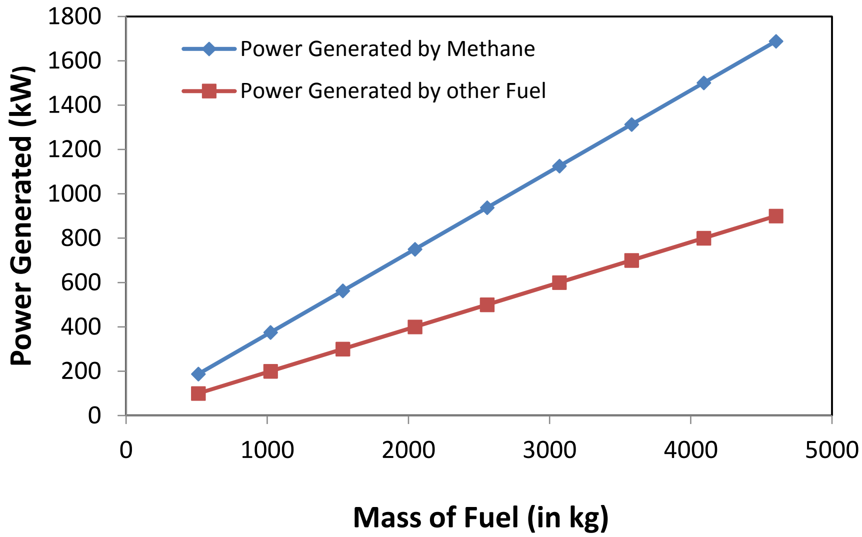

Fig. 11. Graphical comparison between the fuel types.

4. CONCLUSION

Electricity is a social, economic necessity of a country. It is a major factor for the rapid development of any society and the transformation of any economy. The feasibility of using empty palm fruit bunch (EPFB), an abundant renewable energy resource for the generation of electricity was investigated. The power plant used for this research is owned by PRESCO Nigeria Limited. From the study, 896kg of EPFB produced 1.7MW of electricity when the steam boiler was used. This shows that EPFB is a very good alternative for power generation. Based on the findings from the study, other agro-based biomass can also be studied for the generation of electricity using cogeneration plant.

REFERENCES

1. Bajaj S, Singla D, Sakhuja N. Stability testing of pharmaceutical products, J Appl Pharm Sci. 2012;02(03):129-138.

1. Osaghae OJ. Potential biomass based electricity generation in a rural community in Nigeria. Master thesis, Department of Applied Physics and Mechanical Engineering. Division of Energy Engineering, Lulea University of Technology. 2009:1-25.

2. Dimple E. Small–Scale Electricity Generation from Biomass, International J Sci Technol. 2011;5:43-46.

3. Kate R, Deshmukh G, Tandale MS. Energy from biomass – a perspective under Indian conditions. Proc. of the International Symposium. Advances in Alternatives and Renewable Energy. Organised by University Technology Malaysia, Johor, Malaysia. 1997:63-69.

4. WRM. World Rainforest Movement; Nigeria: Palm Oil deficit in a traditional Palm Oil Producing Country. 2001;

5. Abdullah N, Sulaiman F. The oil palm waste in Malaysia, International J Sci Technol. 2013;2(5):839-846.

6. Maulud AL, Saidi H. The Malaysian Fifth Fuel Policy: Re-strategising the Malaysian Renewable Energy Initiatives, Energy Policy. 2012;48:88-92.

7. Aghamohammadi N, Reginald SS, A Shamiri, Zinatizadeh AAL, Wong LP, Sulaiman NMBN. An investigation of sustainable power generation from oil palm biomass, Chemical Engineering J. 2016;8:416.

8. Hussain A, Ani FN, Darus AN. Thermo chemical behavior of empty fruit bunches and oil palm shells waste in circulating fluidized Bed combustor (CFBC), Journal of Oil Palm Research 2006;18:210-218.

9. Umikalsom MS, Ariff AB, Karim MIA. Saccharification of pretreated oil palm empty fruit bunch fiber using cellulase of *Chaetomium globosum*, J Agric Food Chem. 1998;46(8):3359–3364.

10. Han MH, Kim Y, Kim SW, Choi G-W. High efficiency bioethanol production from OPEFB using pilot pretreatment reactor. Journal of Chemical Technology and Biotechnology 2011;86:1527-1534.

11. Misson M, Haron R, Kamaroddin MFA, Amin NAS. Pretreatment of empty palm fruit bunch for production of chemicals via catalytic pyrolysis. Bioresource Technology 2009;100:2867–2873.

12. Geng A. (March 20th, 2013). Conversion of Oil Palm Empty Fruit Bunch to Biofuels, Liquid, Gaseous and Solid Biofuels, Zhen Fang, IntechOpen, DOI: 10.5772/53043. Available from: https://www.intechopen.com/books/liquid-gaseous-and-solid-biofuels-conversion-techniques/conversion-of-oil-palm-empty-fruit-bunch-to-biofuels

13. Roddy DJ, Manson-Whitton C, in Comprehensive Renewable Energy, 2012.

14. Pandey A, Biofuels: Alternative Feedstocks and Conversion Processes, Biomass, Biofuels, Biochemicals, 1st Ed., 2011

15. Ogi T, Nakanishi M, Fukuda Y, Matsumoto K. Gasification of oil palm residues (empty fruit bunch) in an entrained-flow gasifier, Fuel. 2010.

16. van der Stelt MJC, Gerhauser H, Kiel JHA., Kiel JHA, Ptasinski K. Biomass upgrading by torrefaction for the production of biofuels: a review, Biomass and Bioenergy 2011;35(9):3748-3762.

17. Uemura Y, Omar WN, Tsutsui T, Bt Yusup S. Torrefaction of oil palm wastes, Fuel. 2011;90:2585-2591.

18. Olisa P, Kotingo KW. Utilization of palm empty fruit bunch (PEFB) as solid fuel for steam boilery, European J Eng Technol 2014; 2(2).

19. Rajput RK. Basic steam power cycle: Thermal engineering. New Delhi: Laxmi. 2009.