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Research article

THE POTENTIAL EFFECT OF COGENERATION SYSTEM IN COMBATING CLIMATE CHANGE

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Abstract

The energy problems in Ghana and Africa in general have perpetuated the need for sustainable energy production sources. One of the sustainable energy production systems is the cogeneration system. Cogeneration is the simultaneous production of useful heat and energy by using a primary fuel which is supposed to be easily available. It is fast gaining grounds, especially in the timber industry as an efficient means of maximizing the usage and economic value of wood residue. This research was carried out to assess the cogeneration system of Samartex Timber and Plywood Company, Ghana. The input and output volumes of logs (irrespective of species) at the four production departments of the company (sawmill, plymill, veneermill and the moulding mill) were calculated to identify the estimated wood residue volume generated at each department. The quantity of electricity generated from the residues was calculated to assess the rate of electricity production. The company had an average percentage residue of 44.50%. This yielded a volume of 619.654 m^3 per month which was able to generate an estimated electricity of 2,408,055.694 Kw/h per month. It was realized that any wood species can be used for cogeneration but its feasibility depends on continuous supply of the primary fuel. The amount of carbon dioxide (CO_2) emitted during the burning of wood residue is typically 90% less than when burning fossil fuel which helps to reduce the amount of carbon in the atmosphere which reduces the global warming. It is recommended that the system should be practiced in the timber industry which usually has enough wood residues for primary fuel.

Keywords: Cogeneration, wood residue, climate change and percentage residue

INTRODUCTION

The issue of climate change has long been a common concern for all the human races. Climate change, which is a term for the change in climate as a result of the direct or indirect human activities that alters the global atmosphere composition over a period of time, has adverse effects which call for the widest possible cooperation by all countries to at least reduce or halt. Its effects threaten the very foundation of human life on earth (UNFCCC, 2013). One of the contributors to climate change is the reduction of the forest cover through excessive production of wood residue leading to lesser yield volume.

Forests store large quantities of carbon and contain more biomass per hectare in vegetation than other biomes; therefore a decrease in its coverage area will enhance higher rates of carbon release into the atmosphere to cause global warming and consequently climate change (Gorte and Sheikh, 2010). Wood residue is one of the most abundant and environmentally friendly biomass resources especially in the wood industry. Manufacturers generate an enormous amount of wood residue in the process of making products such as lumber, furniture, pallets and paper. In general, less than 50 percent of trees end up in a final product, the balance representing a vast under-utilized resource. Increasing yield through wood residue usage would help to reduce the rate of forest tree harvesting.

Dost (1966) defined wood residue as the remnant of the original raw material after the economic value has been removed. NISER (1974) also defined wood residue as the pieces of materials that are lost from the process of harvesting up to when the final products have been taken. Hence, residues may be regarded as negative product of wood processing. In Ghana, there is a problem with sustainable power supply marked by its common power outages. The timber industry is one of the high energy consuming industries in Ghana. This industry is characterized by relatively low conversion efficiency, leading to a lot of wood residue being generated, hence the principal producer of wood residues (FAO, 2005). There is a great potential of utilizing these residues for energy generation. These residues contain energy and instead of being allowed to go waste in the environment, it can be used to generate electricity to power the processing machines in the factory. Wood residue contains potential energy which can be harnessed to generate electricity through the cogeneration system (EERE, 2004; Enters, 2001). This system is the simultaneous production of useful heat and electricity using a primary fuel. The technologies for converting wood to energy are well established. No other type of fuel has been used successfully in more types of system designs than wood or wood residues (The Renewable Energy Institute, 2010). The Cogeneration, also known as "Combined Heat and Power" (CHP) is more attractive than the conventional power and heat generating options due to:

- Its relatively lower capital investment.
- Reduced fuel consumption.
- Reduced environmental pollution

This cogeneration system is known for its 85% efficiency as against modern electricity plants which usually have 55% efficiency. Through this system the emission of one of the greenhouse gases carbon dioxide (CO_2) is reduced significantly to about 90% which also aids in carbon sink (Smit, 2006). This study was carried out to identify how much electricity can be generated from a given volume of wood residue at one of the leading timber industries in Ghana which has a cogeneration plant.

MATERIALS AND METHODS

The study was carried out at Samartex Timber and Plywood Company Limited, one of the leading timber companies in Ghana. It is located at Samreaboi in the Amenfi West District, in Western Region of Ghana. Samartex Timber and Plywood Company have four main production departments, namely: the plymill, sawmill, moulding mill and the veneer mill.

The species that were used in the study were ***Antiaris toxicaria*** (Kyenkyen), ***Daniellia thurifera*** (Sopi), ***Khaya ivorensis*** (Mahogany), ***Tieghmella heckelii*** (Makore), ***Anigeria robusta*** (Asanfina) and ***Erythrophleum ivorense*** (Potrodom).

Steel tape and fibre tape measure were used to take the diameter and length measurements of the logs respectively. The diameter measurements excluded the bark. Ten logs each from the four production departments at Samartex (Ply mill, Sawmill, Veneer mill and Moulding mill) were randomly selected and their respective input and output volumes calculated. In all 40 logs were used.

Volume calculation of each of the logs, before processing was carried out using the Smalian's formula;

$V_1 = 0.7854 D_{av}^2 L$ (m^3) **Equation 1**

(Brack and Wood, 1997).

Where,

V_1 = volume of log (m^3),

D_{av} = Average diameter of the logs (m),

L = Log length (m)

0.7854 = Constant

The volumes of products produced (plywood, veneer, lumber and mouldings) during the study was calculated using the following formulae:

The formula for the volume of the fixed width products was given by;

$V_2 = [L \times W \times T]\, n$ **Equation 2**

Where,

V_2 = Volume of the product (m^3)

L = Length (m)

W = Width (m)

T = Thickness (m)

n = Total number of pieces of products obtained.

The random width products were tallied. The length, width and thickness, were measured and the volume was given by;

$V_2 = L \times T \times W_t$ **Equation 3**

Where,

V_2 = Volume of the product (m^3)

L = Length (m)

W_t = Total Width (m)

T = Thickness (m)

The sum of the volume of the products was the total volume of products obtained after conversion. The percentage yield or percentage recovery was given by the ratio of the volume of the products (output) to the volume of the input log in metres cube expressed in percentage as defined by Tsoumis (1991).

The Recovery Rate was calculated using the formula,

$RR = \frac{V_2}{V_1} \times 100$ **Equation 4**

Where,

RR = Recovery Rate (%),

V_2 = Volume of products obtained after conversion (m^3),

V_1 = Volume of round logs before conversion (m^3)

The total volume of wood residue generated from the conversion of logs was given by the difference between the log volume and the total product volume and was calculated using:

$V_R = V_1 - V_2$ **Equation 5**

Where,

V_R = Volume of wood residue (m³)

V_1= Volume of round logs before conversion {bolt} (m³)

V_2 = Volume of product obtained after conversion (m³).

The percentage residue was therefore calculated using the formula

Percentage of residue = $\frac{VR}{V1} \times 100$ **Equation 6**

Moisture meter was used to measure the moisture content of some of the residues selected randomly and the averages recorded. The moisture content is recorded because moisture content affects the energy content of wood when burnt and the amount of wood fuel required to achieve the desired heat or steam outputs (JUCA, 2011). The value was used to mathematically calculate the densities of the wood at that moisture content, by comparing it with their densities at 12% moisture content.

The average mass of residue generated per month was calculated as below:

Average Mass = $\frac{A_d}{A_i}$ **Equation 7**

Where,

A_d = Average Density of all species involved

A_i = Average Monthly input volume for all the mills

The averages of the following parameters of all the mills were also calculated: percentage residue, conversion efficiency, species densities and monthly input. The average amount of electricity in Kilowatts per hour (Kw/h) that was generated was recorded from electric meters. This was done for seven continuous days (from Monday to Monday) and the average daily electricity generated was calculated. From enquiries at the study site, it was acknowledged that at least 4 tons of residues were needed for the turbines to generate their daily amount of electricity. This was known as a result of previous research by the company into the quantity of residue needed by the cogeneration plant for its daily electricity production. The capacity of the turbines was therefore stated as: 4 tons of wood residues generate the average daily electricity produced by the turbines. This was used to calculate the electricity produced per month, by multiplying it by the average mass of residue generated per month by the four mills.

Figure 2 and Table 1 show that the veneer mill had the highest amount of percentage residue that was generated (53.15%), with respect to its input volume. It was realized that log flitching contributed much to the residue that was generated. This was due to the fact that quarter sawing was used in the flitching of the logs. Mills using the quarter sawing pattern usually experience a sharp decline in yield volumes, giving rise to high residue generation. According to Ontario Woodlot Association (2000) quarter sawing takes more time and results in

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lower yields per log and narrower boards. The Moulding mill had many processing procedures to reach its final product and this contributed to its high residue generation (52.95%). The Plymill had a residue of 43.66% thus a recovery of 56.34%. It was realised that the plymill had quite a number of processing stages which contributed to its high residue percentage. According to FAO (1990) and Enters (2001), plymills usually have a recovery rate of about 43-50% and this study confirms it. The Sawmill had the lowest residue generated (28.23%). However according to Nketiah *et al.* (2001) lumber recovery in sawmills is about 30-45% of the log input, with residue of about 55-70%. The low level of residue could be attributed to the downstream processing at the study area. Also, live sawing pattern was used. According to Walton (1974) in live sawing there is little waste.

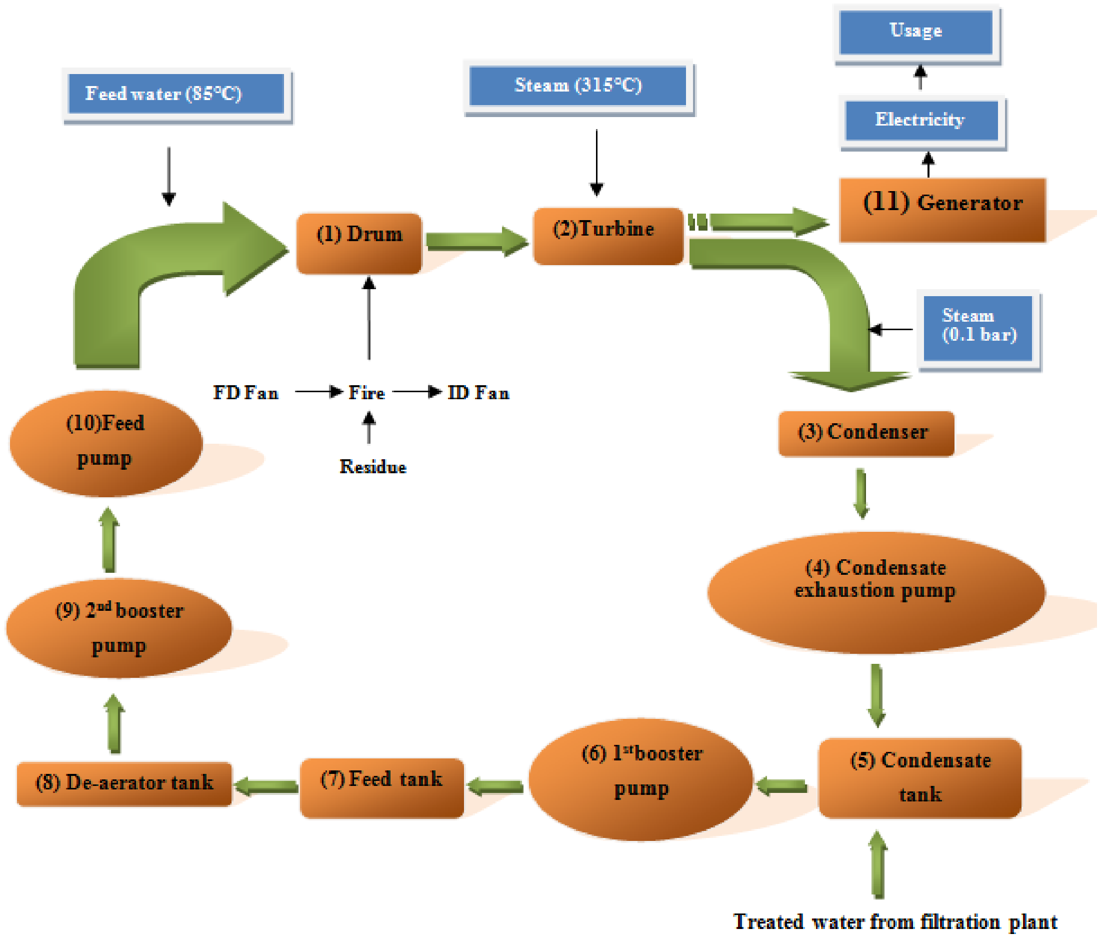

Fig 1: Simplified Electricity Generation at Samartex

ID Fan-Induced Draft Fan (Takes air out of the furnace)

FD Fan- Force draft fan (blows air into the furnace)

RESULTS AND DISCUSSION

Percentage Residue at the various mills

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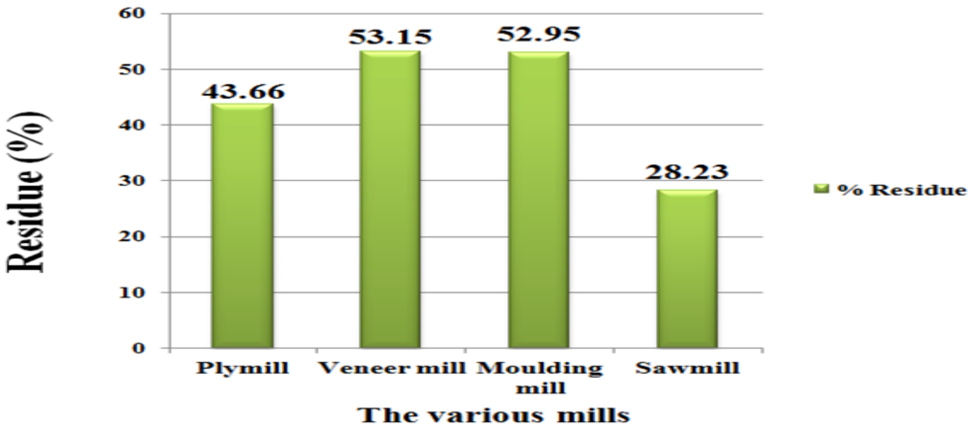

Fig. 2 : Percentage Residue at the various mills.

Table 1.0: Parameters at the various mills

Department	Input (m^3)	Output (m^3)	Residue Generated (m^3)	Residue Generated (%)	Conversion Efficiency (%)
Plymill	16.323	9.196	7.127	43.66	56.34
Sawmill	15.394	11.049	4.345	28.23	71.77
Veneer mill	55.407	31.000	29.447	29.447	53.15
Moulding mill	65.887	31.000	34.887	52.95	47.05

Residue and Conversion Efficiency of the four mills

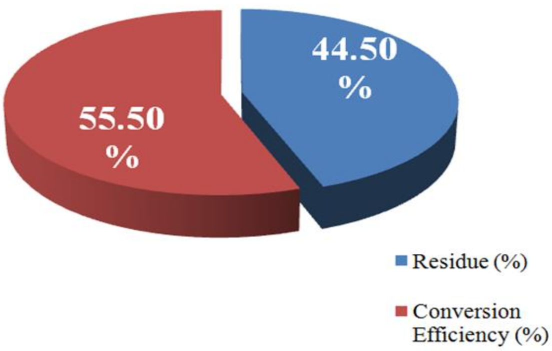

Fig. 3: Percentage Residue and Conversion Efficiency at the mills

Figure 3 shows that an average percentage residue of 44.50% was produced at the four departments. However Sekyere and Okyere (2007) reported 49% residue of most timber industries in Ghana. This means that Samartex produced high yields after processing the logs. The reasons for the high conversion efficiency at Samartex were due to the following factors; most of the logs had larger diameters and longer length. The average length and diameter at all the mills were 5.94m and 1.2m respectively. According to Adams (2007), length and diameter are the major factors that contribute to high conversion efficiency. Samartex is situated in the high forest zone of Ghana and has about thirteen concessions. This has provided a lot of possibilities for the company to acquire logs of larger diameters and longer lengths.

Average Density of all Species involved was given by the sum of the densities of the species (six) divided by 6. This was 621Kg/m^3. Average monthly Input for the mills was given by the sum of the average monthly input of the four departments. This was 1,392.485m^3. The estimated volume of residue produced monthly was given by 44.50% of 1,392.48. Thus the monthly volume of residue was 619.654m^3. From turbine readings at the power station, the quantity of electricity produced daily by the cogeneration plant was 25,031.43kw/h. This means that a monthly wood residue volume of 619.654 m^3 generated 25,031.43kw/h daily and 750,942.90 kw/h or about 750 Mw/h monthly. Whiles generating this amount of electricity the carbon dioxide emissions to the atmosphere was 90% less than that of fossil fuels. The wood residue being used as the primary fuel in this system contains no heavy metals or sulphur which contributes to acid rain production (IEA, 2007).

CONCLUSION

The most important fact is that wood is a renewable raw material. Wood products require relatively little energy and cause little pollution to the environment. It is no longer, however, adequate to refer to these qualitative statements; the environmental impacts must be confirmed quantitatively. In the future all producers will have to demonstrate the consumption of energy and resources as well as the emissions to the environment caused by their products. The wood residue volume of 619.654 m^3 generated 25,031.43kw/h daily and 750,942.90 kw/h or about 750 Mw/h monthly. The production of this amount of electricity through the cogeneration system was associated by a 90% less carbon dioxide emissions. Enhancing the application of the cogeneration system in manufacturing industries especially the wood or timber industry would greatly reduce the rate of carbon dioxide released into the atmosphere and enhance carbon sink to the reduction of global warming and climate change as a whole.

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