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Systematic Review

Possibility of Efficient Utilization of Wood Waste as a Renewable Energy Resource in Ghana

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Abstract

Objective: Ghana has an abundance of energy resources, including biomass, hydrocarbons, hydropower, solar, and wind. The purpose of this work is to explain the importance of using, woody biomass in particular as a renewable source of energy. To improve the utilization of all types of woody biomass, particularly those that are currently considered waste, this paper provides an analysis and overview of the possibilities for using wood waste as a renewable energy, as well as the challenges that producers in Ghana face due to underdeveloped markets and a large amount of capital required to begin production of briquettes and pellets.

Methods: The research strategy is based on the use of secondary data obtained from the internet, as well as analytic and synthetic methods in the preparation of the paper. As a data source, the literature on the production and use of biomass was used. The "Journal of Renewable Energy Review" and other expert literature were used to determine the energy potential of woody biomass residues in Ghana.

Results: More than 3.5 million m^3 of wood is cut annually in Ghana to meet the energy demand. Wood biomass has traditionally been used for energy but the way it is used is outdated, and its efficiency is extremely low. Additionally, the current situation on wood biomass, management of waste in saw mills and, the need for future development of the industrial development is also briefly described. It is of great necessity to fulfill what is outlined in the Convention on Climate Change to transition to a more modern method of producing and using woody biomass.

Conclusion: Biomass has the potential of replacing 25% of the total energy production. Woody biomass process at sawmills generates more than 20% of residues in form of briquettes and pellets, most of which are not exploited. Creation and utilizations wood waste is limited due to lack of technologies, markets, pollution of environment with primary and secondary waste, etc.

Keywords: wood waste, renewable, biomass, climate change

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1 INTRODUCTION

Ghana has rich energy resources such as biomass, hydrocarbons, hydropower, solar, and wind. In spite of these resources, the energy sector in Ghana, has been plagued by lack of sufficient capacity by the producers of power to satisfy the current demand[1]. Ghana has passed the Renewable Energy Act, to address the energy crisis. Since the implementation of the Renewable Energy Act, Ghana has achieved tremendous progress in the deployment of renewable energy. A growth in energy consumption relative to energy supply has been witnessed in Ghana similar to other Africa countries with in the last decade[1]. Ghana's woods are diverse, with forest that are wet evergreen located in south and north having forests that semi-deciduous.

In Sub-Saharan Africa, traditional energy sources such as firewood and charcoal account for more than 80% of overall energy use[1]. The Government of Ghana has announced various strategies and choose expansion of generation capacity of renewable energy to 10% by 2020 to contribute higher to the energy generation mix[2]. Biomass has been identified as a renewable and widely available resource with enormous potential for energy production or conversion into other raw materials, and can particularly be valuable in community-based projects. Furthermore, animal and plant waste such as straw corn stalks, sugarcane leavings residue and bagasse, and cereal husk, and nutshells are all examples of biomass waste from agriculture[3].

Ghana has close to 90% of the entire wood fuel used being obtained directly through the standing forest, while the remainder is from residues that results from activities of logging and sawmill and many others. Heavy reliance on wood for fuel has significantly resulted into deforestation that is being witnessed within the past decades in Ghana. The forest cover of the country has been dwindling from 8 million hectares to 1.6 million hectares since the beginning of the century[4-7].

It has been difficult to regulate the biomass energy industry in Ghana. The Energy Commission has recently begun the introduction of a ban on the exportation of charcoal produced from the sources that have not been approved. Standing forests are among the sources which are considered to be unapproved, also on the other side, residue produced by the sawmills and the forest establishment for the purpose of the production of the charcoal makes up the approved sources. Energy Commission has been providing permit to the legitimate exporters of charcoal as per the guidelines of the government[8].

2 MATERIALS AND METHODS

This research strategy is founded on the use of secondary data from the internet as well as analytic and synthetic methods were also used in the preparation of this paper. The literature on wood biomass production and consumption was used as a data source. The "Journal of Renewable Energy Review" was used in conjunction with other expert literature to determine the wood biomass energy potential residues in Ghana. The purpose of this work is to explain the importance of using to the greatest extent possible, wood biomass as a major renewable energy source representing a friendly fuel to the environment derived from sources that are replenishable, thus wood as a source of fuel is among the options to lower greenhouse gas emissions.

3 RESULTS AND DISCUSSION

3.1 Types of Biomasses and the Importance of Their Use

Energy from biomass materials is Ghana's most important source of energy, accounting for around 64% of the country's primary energy[6]. Biomass is an organic material that can be used as source of energy source, such as wood, cereals, seaweed, or animal waste. After the sun, biomass is likely the oldest source[9,10].

Studies show that 40% of the population in Ghana is employed within the agriculture sector. The enormous biomass resource agriculture base shows bioenergy potential[11]. Biomass still has a lot of potential for enhancing the country's energy security, through combination with the development of other technology used for conversion[11].

According to studies, palm oil mill factories in Ghana are four in number. These industries are currently generating power using biomass waste from palm tree. This is evident Palm Biomass is available in Ghana and is a potential renewable source. It is concluded that palm biomass is one of the possible types of biomasses available in Ghana[11].

Another study by Kuunibe et al.[9] in Ghana found agricultural biomass wastes as another type of biomass. Examples are animal husbandry waste, stalks, straw, and sugarcane trash, sugarcane bagasse, cereal husk, nutshell, etc[12].

Sawdust from sawmills, coconut husk, sugarcane trash, and palm kernel shells are generated each year in huge quantities. This large amount of Biomass from agricultural activities is considered trash and pollutants in Ghana[12].

Some regulations and the renewable energy roadmap identified forestry goods, wood wastes, horticulture, and viticulture products and residues obtained from pruning, agricultural, animal rearing, and related industry goods, as well as the decomposable part of manufacturing and municipal garbage as biomass types in Ghana[13]. Biomass is a renewable energy source that comes from plant materials which include plants parts such as timber, grass, stalks of the grain crops, etc. is thus separated into the wood, animal, non-wood, municipal solid waste, and manufacturing waste, with some distinctions[13]. Ghana has an estimated 60% of its total energy from wood fuel[12].

Biomass is used for energy production while adhering to the notion of sustainability in development. Hunger is on rise globally yet ethanol and biodiesel are produced using food materials, the use of biomass for this purpose must be thoroughly examined, particularly from the perspective of strategic energy logic[13]. Worldwide, the present structure of main electric source of energy cannot support a trend of rising production of energy. The energy crisis and environmental issues are inextricably linked globally[14].

3.2 Raw Material Potential of Wood for Energy in the Forest of Ghana

Ecologically, there are three forest zones in Ghana: a highly forested zone in the south of 8 million hectares, a savanna zone (occupying 14.7 million hectares) mainly in the northern parts, and a transitional zone in the middle (1.1 million hectares). Biomass is Ghana's primary source of energy. Wood fuel is a renewable and sustainable energy supply that can help balance energy supply and demand[15]. The country's entire forest area is between 2.72 and 6.34 million hectares. It covers 23.9 million hectares in total (FAO 2005). Arable lands comprise 17.54%, permanent crops account for 9.22%, and others up to 73.24% of the land.

The concept of sustainability in the forest management has become the primary goal of forest management due to the growing range of communal outlooks and uses of forests. Though the term "sustainability in the forest management" has not yet been given definition, the state and other relevant organizations have devised principles and measures used to assess various forestry operations and adapt management consequently[16]. Environmental criteria assess the state of health, productivity, and biodiversity of the forest of Ghana.

Ghana's High Forest Zone encompasses roughly 82,000km^3, according to Hawthorne (1995). It's divided into vegetation zones which are nine in total, each having its own species of plants and weather patterns. Most of the wood is harvested from the southwest's deciduous and evergreen woods as shown in the Figure 1. Triplochiton (Wawa), Mansonia altissimo (Mansonia), Nesogordonia papaverine (Data), and Khaya (mahogany) are the most common species in deciduous forests, while Guarea cerata (Guarea), Tieghemella (Makore), Tarrietia utilize (Niang on), and Uapaca (Assam)[18].

About 95% of the logs gathered in Ghana are processed by enterprises. Log harvesting is done by about 30% of wood processing enterprises. The rest of the market (5%) of the local wood is served by about 70 small-scale processing plants[18].

3.2.1 The Republic of Ghana Forest Fund

Ghana is on Africa's west coast, with their neighbour Togo to the eastern side, Côte d'Ivoire to the western side, Burkina Faso to the northern side, and Atlantic Ocean to the southern parts[18]. It covers an area of 310 square kilometres with irrigated land. The climate of the southwest is, warm, tropical and relatively dry, while southwest region has hot and humid climate and north part experiences high temperatures and dry[18].

3.2.2 Energetic, Fast-growing Forests in Ghana

Because of their short production cycle, quickly tree species are ideal for producing wood for energy. Plant produces energy that are used substitute fuel in the process of heating. Light fuel oil (distillate oil) are substituted by energy obtained from wood fuel and it help in reduction of emissions of greenhouse gases through lowering carbon dioxide levels[1]. Forests which are rapidly growing are made up of poplar or willow trees that are usually harvested every 2 to 5 years, on average of each and every three years. Establishing, cultivating, and maintaining energy forests contribute to a more convenient supply of Biomass and raw materials suitable to produce briquettes[19]. The most mature trees used as energy crops are sallow (Salix spp. L.), which has a calorific capacity of 19,380kJ/kg and produces 213,488 tons in every hectare. Perennial grasses cultivated as energy plants include switchgrass (*Panicum virgatum*), and has been commercially successfully as compared to the other plants, producing a greater energy and with good quality of combustion quality. Harvesting of *Panicum virgatum. L* is carried out on a yearly basis, and has the calorific value of 19,900kJ/kg. Elephant grass, has a calorific capacity of 19,135kJ/kg and can thrive for at least 15 years. Giant reed (*Arundo donax L.*) produces 40 tons of dry matter for every hectare with a calorific value of 18,035kJ/kg[20].

The potential of the technologies which involves the

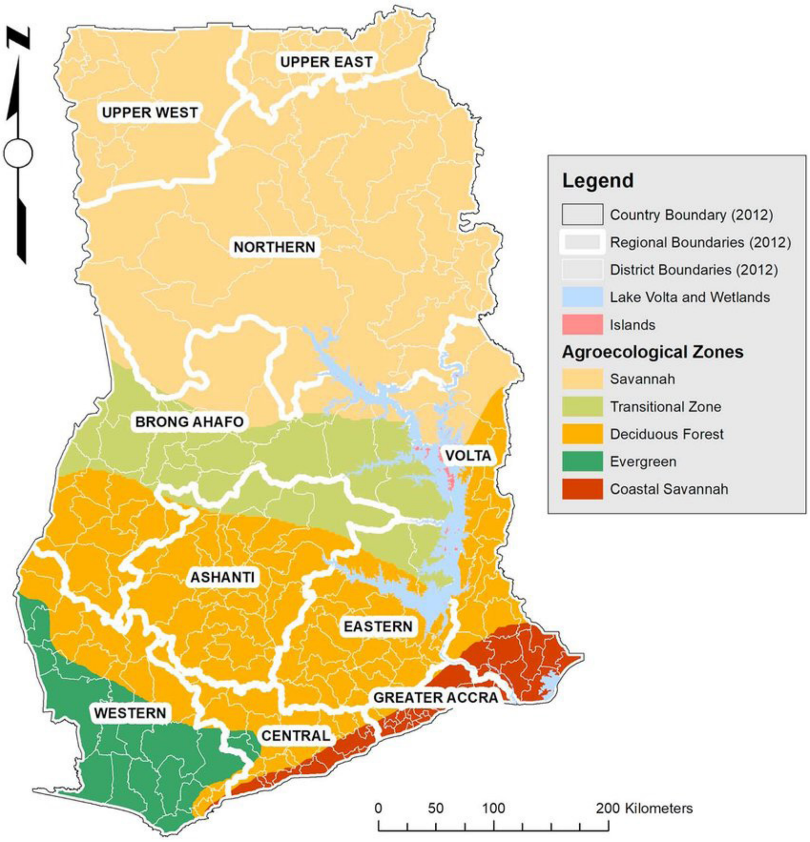

Figure 1. Savannah, transitional zone, deciduous forest, evergreen, and coastal savannah are Ghana's agro-ecological zones[17].

use of wood product to produce energy are commendable in terms of organizational aspects, cutting methods, mechanization degree, and concentration of wood per unit of area. At the moment, Ghana do not have sufficient energy crops, though studies carried out revealed the unsuitability of the land for growing conventional crops however, the land can be ideal to increase the growing of poplar trees, that proliferate and has a capacity of being energy crops[21].

According to the research conducted, land estimated to be 200,000ha in size and found along rivers and canals in plains regions which are unsuitable for agriculture could be used for quickly Populus trees[22]. Planting of quickly populous trees is an option to increase potential of wood energy in Ghana. Tree species such as acacia, is widely and plentifully found in dry areas, with a possibility of an increase of 7m^3/ha annually and a cycle of production within a period of 15 years[23]. Designated new poplar black varieties, with potential of producing approximately 30m^3/ha every year in a concise cycle of production of 7 years, are the suitable trees types in the semi-damp habitat. The American ash tree produces yearly increment of 8m^3/ha for each year in wetlands, and this is considered to be high in clay soils loaded with too much moisture[22].

3.2.3 Wood Production in Ghana

In Ghana, production of wood is articulated through felling of trees and it include every commercial collection of both wood and wastes from wood in official statistical bulletins. In 2009, wood cutting in Ghana totalled 2,609,494m^3 of the forests and a further 25,000m^3 were caried outside forests (parks in cities, canals, trees found along roads, canals, and boundaries), for a total timber logging of approximately 2.63 million m^3.

The forest sector, mainly the export of wood products, is a significant contributor to Ghana's economy. According to reports, the timber industry makes for approximately 11% of the country's overall export revenues. Lumber, furniture pieces, plywood, glulam, and other wood products are among those produced in Ghana for export. Currently forest sector directly supports over 2 million people[24].

In terms of foreign exchange revenues, increased employment, and prospects for local development, Ghana's wood industry makes a substantial contribution to the economy.

It employs about 100,000 people directly in mill processing logging and, as well as public institutions. It also contributes around 4% of Ghana's national tax revenue[16]. Wood cutting assortments include cut wood which undergoes additional cutting and manufacture of different types of technical lumber, wood used in

Table 1. Shows the Average Share of Various Wood Categories in Total Volume[14]

Wood Assortment	Share in the Total Mass (%)
Round wood	38
Stacked wood	30
Roundwood bark (bark peeled from wood for the market)	4
Forest scrap (residues of wood cutting in the forest)	9
Small branches	11
Stumps	8
Total	100

the production of paper and pulp, firewood, providing support to the pillars in mines located underground, and other products from wood, including those used in board production. Majority (50%) of timber harvested from trees in government forests is being used as source of fuel. The remaining half (50%) of timber obtained from trees in the government forests is useful in making furniture, also in making the paper and pulp, for making pillars, and various purposes[23]. Even though nearly 50% of the entire forest are owned by private individuals, the number of forest trees trying for logging in remote forests is three times that of state forests. As a matter of fact, private owners are uninterested in forming their own associations to improve forest management. Aside from tree trunks, which are one kind of forest variety, other waste types exist and are part of biomass material which are also useful, for example sections of the wood that falls off and others that usually remain after processing of wood is completed (Table 1). Forests approximately contain 2.9106m^3 residues from the biomass material with an energy potential of 549,500 tons of oil equivalent[23].

Based on what has been said so far, we can conclude that profitability and efficiency dictate the tree parts and the extend of use. The level of the energy produced by the timber is determined by the raw material's quality. If the wood waste price was reasonable, the technological and technical problems of collecting and transporting wood fragments after a tree was felled, at the moment is one of the major challenges that can be solved In Ghana, approximately 374 companies are involved in the production of furniture and processing of wood. The majority (2360) manufacture sawn timber, wood panels, veneer, and joinery, while the rest 400 in number, manufacture furniture. Small businesses account for more than 90% of all companies involved in this activity. The availability of materials, short payback period and slow investment of capital, and short time of repayment have resulted in many sawmills.

3.3 Waste Derived from Woody Biomass

Waste from wood comes through a variety of sources which varies significantly in terms of composition, and amount. Every of these variables have a substantial impact on the possibilities of using wood waste. The Researcher further noted that wood and wood waste bark, wood chips, sawdust, paper mill leftovers and wood scrap, accounted for around 2.3% of total annual energy consumption in 2020.

According to studies, barks, leaves, branches, roots, discarded trees, stumps, remains after pruning, treetops, and chips all become wood wastes when forests are cleared. Similarly, cutting lumber, stubs, bark, veneer, sawdust, and plywood are all examples of wastes from both primary and end wood processing[25]. Stubs, sawdust, and other solid trash are left behind from the carpentry and furniture-making processes. Wood produces waste in the form of corners, chips, old doors and windows, sheeting residues, flooring, fences, and other items[24].

3.3.1 Wood Waste in Forestry in Ghana

Sawdust and scrap pieces are the waste products coming from sawmills. Residue levels changes and it depends on production potential of wood and facilities, but averagely, they account for roughly 20% of the entire mass of wood treated[13].

In the wood cutting process, 90% of the entire harvest is technical wood and stacked wood; the rest 10% is waste from wood.

Woods have plenty of debris, such as trunks, thinner branches, leaves, and needles, accounting approximately 2% of the total amount of wood. The volume of the parts that are not utilized, including thin branches, of bark, thin branches, and stumps accounts for approximately 42% of the actual volume of the wood.

Each of these residues have the potential to be used as biomass, primarily energy source. The amount of residue used is determined by the infrastructure of the forest, terrain and how far the site of exploitation of residue is located. Forests in lowlands areas, have more accessibility, almost all the cutting residues can be used. Contrary, forest in areas that are mountainous having steep slopes and inadequate infrastructure, have little amount of residues to be extracted.

The ability to utilise waste-restored wood is primarily determined by its contamination with other materials and the likelihood of their removal. Contaminants is eliminated by using mechanical process (bricks, floor coverings, tiles, linoleum, glass, plaster, mortar, soil, rocks, metal components, etc.) or physically or chemically, depending on the species (waxes, various organic protective means, oils, paints and varnishes, adhesives and other additives, water, etc.).

The size of the particles (pieces) and the wood type are the only factors influencing the recycling options for clean waste. Generally, by lowering the "particle" size of the "pieces" and increasing the wood fibre destruction, leads to reduction of the value of the wood (wood dust has less value compared to the chips which are appropriate for producing boards or paper).

3.3.2 Wood Residues in the Wood Processing Industry in Ghana

Based on their size, wood processing produces three types of residues.

- Bark,
- Large after-cut remains, and
- Acceptable waste (wood chips, sawdust, wood dust).

Most large residues have a potential of being recycled. Only a tiny portion of the residue is left unused in order to be used for other purposes, such as briquette production, bio-fuel production, or production of energy. Raw materials used to make solid biofuels (pellets, wood chips) are determined by the market, which determines whether residues from various processes will be used to make panels or pellets.

Almost every by-product, including wood residues, can be useful internally in companies that are well-organized that manufacture panels or pulp and paper. A portion of the residue in sawmills is used internally, but a significant amount is available for other uses, such as pellet production, energy production and direct combustion.

As a result, most wood residues used in the briquettes and pellets production come from forest cutting and sawmills. Other small companies in the wood processing field, also have access to wood residues as well. As a result, average amount of wood residues to produce briquettes and pellets is approximately 1 million m^3, wood residues obtained from forest cutting (approximately 0.6 million m^3), sawmills (about 360,000m^3), and 50,000m^3 or below of wood residues produced by other companies that process wood. Sawdust and scrap pieces are the most common types of wood waste in sawmills. The amount of residue varies depending on capacity of wood produced in addition to the facilities, nevertheless the total sum of percentage is around 20% of the total mass of processed wood.

3.3.3 Wood Waste Management System

The widely accepted rule is involved three significant levels involved in effective waste management: waste reduction, recycling, and reuse. Wood waste generation occurs in all stages of the material's life cycle, and numerous wood occur at all stages of processing.

Overall, wood waste can be divided into two categories: that which occurs as a raw material in the final product production (including trade) and that which is made from previously used wood products.

The best way to managing wood waste is reducing or prevention or reduction of waste products at the source (waste minimization), reintegration of used items and their reuse (for the same or another purpose), that is, reducing the use of resources which may lead to its depletion and or reduce the hazardous nature of wastes.

It is then followed by recycling or in order to obtain raw materials for the manufacture of the same or other products. The option of utilizing waste (composting) comes next, but it is undesirable than waste recycling. Waste that cannot be avoided and cannot be recycled can be deposited or incinerated properly.

Management of waste is a series of activities that include waste prevention, minimization and treatment, waste establishment, operation, closure, and maintenance of waste treatment facilities, monitoring, counselling, and education related to waste management activities, all based on human principles of nature conservation and sustainable development. Controlling industrial waste, which is majorly non-hazardous, differs little from municipal waste treatment. Waste generated by wood processing enterprises (wood residues, sawdust) is treated as a new heating resource (pellets, briquettes).

Management of wood waste has the same goal as any other type of waste management type, which is waste reduction in this case and recycling at sawmills. Recycling of wood waste differs from different types of recycling in that it produces secondary raw materials and end products[26]. By analysing the industry, we can identify several issues that arise in the production and use of waste wood:

- Inadequate utilization of biomass from wood.
- Lack of credible organization in charge of timber industry.
- Insufficient knowledge of new technologies involved in wood waste usage.
- Lack of reliable markets for waste wood waste products.
- Pollution of environment from primary waste generated by cutting and secondary waste generated after immediate and final wood processing.
- Indirect (secondary) pollution caused using other sources of energy other than wood waste.
- Lack of proper regulations on the management of and protection of rest, environmental guidelines for waste disposal, and hazardous gas emissions into the atmosphere.
- Inadequate level for the production and use of renewable energy sources.

By addressing these issues, the benefits of expanding the production and use of wood waste products would be felt, primarily in the reduction in the use of fossil fuels, increasing the use of renewable energy sources, and protection of environmental[26].

3.4 Wood Briquettes

Wood shavings briquettes are the most cost-effective way to use a dependable resource for heating while also being the cleanest way of homes and businesses heating. The use of sawdust waste and coal dust in the manufacture of briquettes provides higher energy-caloric values as compared to high-quality coal and thus contributes immeasurably to environmental health.

Because briquettes are made from cold dust and waste wood, and their use "cleans the environment", using briquettes in any heating system that consumes solid fuel produces no foreign by-products other than those defined by nature. As a result, there are no emission of greenhouse gases and less amounts of ash are produced.

3.4.1 The Technology of Making Briquettes

Bulky biomass must be compacted or packed in the desired size and shape for transporting, handling, storing, and preservation to reach the most remote users. As a result, biomass could become a market commodity, making it more accessible to consumers.

Biomass briquette has several advantages over other biomass production processes. The volume, transport and handling and transport costs are reduced, much less storage space is required, material resistance to deterioration in biological processes is increased, and combustion efficiency is increased. With proper dosing, the energy briquettes can be used in all types of solid-fuel furnaces.

Briquettes have similar energy values to brown coals from Ghana. Furthermore, using briquettes in its place of coal has a significant environmental benefit due to the low sulphur content (causes less pollution with combustion products), and briquette ash can be used as a fertilizer.

Briquettes are made by pressing crushed particles of lignocellulosic material with or without a binder under specific conditions: elevated temperature, high pressure, and optimum moisture content in the material. For briquettes without a binder, the piston impact pressure is 210 bars. The volume of biological material is reduced by about tenfold during pressing, resulting in a volumetric briquette mass of 800-1200kg/m^3.

Press tools are heated to 90 degrees Celsius. The thermoplastic glueing of plant material particles provides the solidity and density of crushed briquettes particles without a binder. Apart from the proper granulation (fragmentation) of the initial material (3-5mm), the moisture content of the material plays a vital role in compressing the biomass. The ideal moisture content is approximately 15%. Briquettes are circular in shape. Briquettes can range in size from 25 to 90mm in diameter and length. Briquettes are typically packaged in shrinkable foil, cardboard, paper, or plastic bags.

The technological process of briquette crushed lignocellulose material without a binder is based on high pressure in the presses the tool from 150 to 200 bars, which converts the biomass into compact and high-volume mass briquettes. To be able to convert biomass into a permanent stable form, the moisture content must range from 10% to 18% (up to 20%), and materials must be granulated up to 5mm.

As a result, drying the biomass naturally is required to ensure these conditions. The biomass volume is reduced by briquette 7-12 times, and the volume mass of the resulting briquettes is 1.0-1.4kg/dm^3. Briquettes are packaged in 10kg cardboard boxes, 25-40kg plastic bags, or shrinking plastic wrap. Briquette packing is required due to the compressed material's exceptional hygroscopicity.

The type of material, fragmentation quality, and moisture content of the fabric all influence the optimum technological process for the formation of briquettes with high-quality energy.

When an adhesive is used as a bonding agent to join connect fragmented particles, the procedure becomes very complex and expensive. The cost of briquette was 74%, accounted for by adhesives.

Therefore, many briquette plant owners abandoned this method of briquet production. Briquette production without the use of a binder (adhesive) contributes significantly to the reduction of production costs while also improving environmental values. In addition, sulphur participation is negligible (6 times less than coal), ash content is 2-7 times less than coal, and moisture content is 2-5 times lower than coal.

3.4.2 Calculation of Calorific Power of Wood Briquettes and Equivalent Heat Energy Sources

The Loznica-based Div-Chabros plans to produce 3300 tons of briquettes per year. The raw material for briquettes is entirely made of beech. The calorific value of beech briquettes in a dry state with 12-15% humidity is 21,683.48kJ (5180kcal).

Briquettes' calorific power reflects their value of energy, and the higher it is, the more energy is supplied by burning, and the elevation of the economical use. Comparisons of the calorific power of briquettes with moisture levels of 10-12% were made with the following fuels: classified oak firewood in m^3, beech firewood in m^3, ash firewood in m^3, compare to lignite coal in tons, brown coal in tons, distilled oil in tons, and natural gas in tons (Tables 2-8).

3.4.2.1 Comparison of Calorific Power of Wood Briquettes with 1m³ of I Class Oak Wood

Oak has an average bulk density of 750kg/m^3 and a calorific power of 14,444,46kJ/kg. The calorific power of dried oak is calculated as the product of average volumetric weight and average calorific power; thus, the calorific capacity of 1m^3 of dried oak is 14,444,46kJ/kg×750kg/m^3 = 10,833,345kJ/m^3.

With 12-15% humidity, the average calorific power of wood briquettes is 21,683.48kJ/kg. The total calorific power of 3,300t of briquettes produced by the DIV-Chabros company is 3,300,000kg×21,683.48kJ/kg = 71,555,484,000kJ. The equivalent heat for one cubic meter of oak wood is 6605.1, which is calculated by dividing the total calorific power of 3,300t of briquettes by the average calorific power of one cubic meter of dried oak.

Heat equivalent (Etoak) = 71,555,484,000kJ/ 10,833,345kJ/m^3 = 6605.1m^3.

Etoak = 6605.1m^3 oak wood (Table 2).

3.4.2.2 Comparison of Calorific Power of Wood Briquettes with 1m³ of I Class Beech Wood

A cubic meter of dried I class beech wood has an average bulk density of 720kg/m^3 and a calorific power of 14,842.20kJ/kg. 1m^3 of beech has a calorific power of 720kg/m^3×14,842.20kJ/kg = 10,686,384kJ/m^3. The briquettes have a total calorific power of 71,555,484,000kJ.

Heat equivalent (Etbeech) is equal to 6695.9m^3 = 71,555,484,000kJ/10,686,384kJ/m^3.

Etbeech is equal to 6695.9m^3 of beech wood (Table 3).

3.4.2.3 Comparison of Calorific Power of Wood Briquettes with 1m³ of I Class Ash Wood

Dried I class ash wood has a bulk density of 690kg/m^3 and a calorific power of 16,077.30kJ/kg per cubic meter. 1m^3 has a calorific power of 690kg/m^3×16,077.30kJ/kg = 11,093,337kJ/m^3. The total calorific power of the briquettes is 71,555,484,000kJ. Heat equivalent (Etash) = 6450.3m^3 = 71,555,484,000kJ/11,093,337kJ/m^3. Each is equal to 6450.3m^3 of ash wood (Table 4).

3.4.2.4 Comparison of Calorific Power of Wood Briquettes with 1t of Lignite

Lignite coal has a calorific value ranging from 8373.6 to 16,747.2kJ/kg dry coal. For comparison, the average calorific power is 12,560.4kJ/kg. A ton of lignite has a calorific value of 1000kg/12,560.4kJ/kg = 12,560,400kJ. Dry briquettes have a total calorific power of 3,300,000kg×18,597.765kJ/kg = 61,372,624,500kJ. Heat equivalent (Etlignite) (Table 5).

Etlignite = 61,372,624,500kJ/t = 4886.2t

Etlignite is equal to 4886.2t of lignite coal.

3.4.2.5 A Comparison of the Calorific Power of Wood Briquettes and 1t Brown Coal

Brown coal has a calorific value ranging from 16,747.2 to 20,934kJ/kg in the dry state. Average calorific power of 18,840.6kJ/kg was used for the calculation. A ton of brown coal has a calorific value of 1000kg×18,840.6kJ/kg = 188,406,000kJ.

Briquettes with 0% moisture have a total calorific power of 61,372,624,500kJ. Heat equivalent: 61,372,624,500kJ/188,406,000kJ/t = 3257.5t Etbrown coal

3257.5t brown coal = Etbrown coal (Table 6).

3.4.2.6 Comparison of Calorific Power of Wood Briquettes with 1t of Distilled Oil

1kg of distilled oil has a calorific value of 41,239.98kJ/kg. The calorific value of one ton of distilled oil is 1000kg×41,239.98kJ/kg = 412,399,800kJ. In a dry state, the briquettes have a total calorific power of 61,372,624,500kJ.

Etdistilled oil has an equivalent heat of 61,372,624,500kJ/412,399,800kJ/t = 1488.2t.

1488.2t distilled oil = distilled oil (Table 7).

3.4.2.7 Comparison of Calorific Power of Wood Briquettes with Natural Gas for Household (Such as Propane or Butane)

Gas has a calorific value of 45,636.12kJ/kg for households. A tonne of household gas has a calorific value of 1000kg×45,636.12kJ/kg=456,361,200kJ. Briquettes have a total calorific value of = 61,372,624,500kJ when dry.

Etgas = 61,372,624,500kJ/456,361,200 kJ/t = 1344.8t Equivalent heat,

1344.8t of gas = Etgas (Table 8).

According to the calculations, the total wood waste from a single sawmill in Ghana can produce sufficient briquettes to replace 6605m^3 of oak wood, 4886t of lignite coal, 3257t of brown coal, or 1344.8t of gas for households, which are not insignificant amounts of energy[25].

The tables were used present the characteristics and energy value of briquettes and pellets as compared to other fuels[25]. While there is extensive information of

Table 2. Comparison of Calorific Power of Wood Briquettes with 1m^3 of I Class Oak Wood

Type of Fuel	Weight (kg/m^3)	Humidity (%)	Calorific Value (kJ/kg)	Total Caloric Value	Equivalent Heat (m^3)
Oak wood	750	-	14,444.46	10,833,345 (kJ/m^3)	6605.1
Briquette	3,300,000	12-15	21,683.48	71,555,484,000 (kJ)	

Table 3. Comparison of Calorific Power of Wood Briquettes with 1m^3 of I Class Beech Wood

Type of Fuel	Weight	Calorific Power (kJ)	Total Caloric Value (kJ/kg)	Heat Equivalent (m^3)
Dried I class beech wood	720 (kg/m^3)	14,842.20	10,686,384	6695.9
Briquettes	3,300,000 (tonnes)	21,683.48	71,555,484,000	

Table 4. Comparison of Calorific Power of Wood Briquettes with 1m^3 of I Class Ash Wood

Type of Fuel	Bulk Density (kg/m^3)	Calorific Power (kJ/kg)	Total Caloric Value (kJ/m^3)	Heat Equivalent (m^3)
Dried I class ash wood	690	16,077.30	11,093,337	6450.3
Briquettes	3,300,000 (tonnes)	21,683.48	71,555,484,000	

Table 5. Comparison of Calorific Power of Wood Briquettes with 1t of Lignite

Type of Fuel	Weight (kg)	Calorific Power (kJ/kg)	Total Caloric Value (kJ)	Heat Equivalent (t)
Lignite coal	1000	12,560.4	12,560,400	4886.2
Briquettes	3,300,000	18,597.765	61,372,624,500	

Table 6. A Comparison of the Calorific Power of Wood Briquettes and 1t Brown Coal

Type of Fuel	Weight (kg)	Calorific Power (kJ/kg)	Total Caloric Value (kJ)	Heat Equivalent (t)
Brown coal	1000	18,840.6	188,406,000	3257.5
Briquettes	3,300,000	18,597.765	61,372,624,500	

Table 7. Comparison of Calorific Power of Wood Briquettes with 1t of Distilled Oil

Type of Fuel	Weight (kg)	Calorific Power (kJ/kg)	Total Caloric Value (kJ)	Heat Equivalent (t)
Distilled oil	1000	41,239.98	412,399,800	1488.2
Briquettes	3,300,000	18,597.765	61,372,624,500	

Table 8. Comparison of Calorific Power of Wood Briquettes with Natural Gas for Household Use

Type of Fuel	Weight (kg)	Calorific Power (kJ/kg)	Total Caloric Value (kJ)	Heat Equivalent (t)
Gas	1000	45,636.12	456,361,200	1344.8
Briquettes	3,300,000	18,597.765	61,372,624,500	

briquettes in Ghana, they are rarely used, therefore, foreign producers are much concerned with this issue of rarely used information. It is challenging to present a calculation that demonstrates the benefits of using briquettes in Ghana, since majority of the researches used for this particular study have been carried out by the foreign manufacturers from Germany, Denmark, Sweden.

3.5 Market, Economy and Policy

The briquette market in Ghana is underdeveloped because it requires companies engaged in this activity as well as product consumers to exist. In Ghana, there are companies that manufacture briquettes from wood and also pellets, but because they are not able to get consumers in this area, all the production are exported[23].

Due to increase in number of companies dealing with briquettes production, there is also a sign of potential of briquettes manufacturers experiencing rapid growth. The incorporation of such product into day to day life entails the installation of specialized tools and equipment such as heating boilers.

Pellet boilers are far more expensive than gas pipelines, making them an unattainable investment for Ghanaian households getting average income[23]. Except in major cities, it is currently impossible to purchase a boiler utilizing pellets in Ghana, and even more challenging to find specialists to be involved in the installation and maintenance. Ghana has the raw materials, technology and domestic producers, as well as foreign investments and international organization support, which enables the country to make use of the pellets including all other forms of biomass[12].

Nevertheless, there is no regulations in place to raise awareness concerning environmental and economic feasibility on the use of such types of energy, as well as the concept of Ghana's future energy. Wood pellets can be produced using raw materials obtained either the sawmills or directly from the forest. The current wood waste price from the forest to wood pellets manufacturers is less than 205.39GHC/ton[23].

Presuming that the cost of transporting wood waste using truck is comparable to the cost of transporting coal, which ranges from 0.7 to 11.50GHC/km for distances range up to 50km for a car with a 25t capacity. The price is heavily influenced by the wood waste transport density[27].

The briquette plant should be located near a wood production area for practical and economic reasons, as this would reduce raw material transportation costs. Briquettes production and the establishment of plants for both the production of pellet and briquette are significant in terms of the environment and its conservation[16].

In addition to the wood sawdust solid pieces, briquettes are made, which is a problem in every sawmill due to disposal. Sawdust is not harmful to the environment if it is not stored for an extended period. When sawdust meets rainwater, it leads to the production of manganese and phenol, both of which causes harm to human health, which is yet another reason for the recommendation of using sawdust in making briquettes[16].

Alternatively, the area where the sawdust is deposited, which is primarily accessible on the land where the sawmill is located, will finally necessitate rehabilitation, and to do so, 3-4m holes depth will need to be dug in the ground, and they depend on the amount of sawdust deposited[24]. Table 9 shows that briquettes and pellets have significant energy potential and that the amount of ash is low significantly lower than coal.

Only in this manner contamination of soil and groundwater could be avoided. It should be noted that the next process of rehabilitation is not completed in Ghana. This is typically resolved by transporting sawdust to the town dumping site, which then becomes people's responsibility in charge of landfill operations, and the polluter has nothing more to do with it[1].

Predicting the total annual wood consumption for energy, including the private forests cut down trees and timber which was not documented, firewood from government forests, and woodcut outside of forests, the total firewood consumption annually is not less than 3.5 million m^3[11].

Reduced firewood consumption necessitates producing alternative ways that can be used for purposes such as briquettes production. This reduces the volume of wood used for heating by utilizing waste generated during the manufacturing process of the wood industry. If the goals are to be met, the state must be willing to accept and support industrial production innovations[11].

In Ghana, there is currently no developed market for briquettes. The knowledge and technology transfer from other countries would be highly beneficial in the formation of markets. The state's financial support through non-repayable subsidies system is critical. It is important to establish good credit support for investors as soon as possible and foreign investment support. Capacity development in the biomass sector must coincide with the expansion of production capacity[16].

There are no legal conditions in Ghana for both the production and consumption of wood fuel, the service and wood biomass production as energy sources, or intensively use of this energy source. The importance of using biomass from wood as an energy source is becoming increasingly important in the forestry sector[22].

4 CONCLUSION

Biomass can replace about 25% of today's total energy in Ghana. At the moment, the production of the energy provides for the 25% of the energy requirement of the country, which makes Ghana to continuously rely on the imported energy. The country has high consumption of the fossil's fuels of about 93% of the entire energy consumed while the usage of renewable energy is estimated to be 7%. Biomass specifically from wooden and agricultural sources have not been fully exploited with an estimate of 80% untapped energy potential in it. The generation of residues in basic wood processing in sawmills is more than 20%. Briquettes are produced from single piece waste which are mechanically treated, sawdust, bark as well as other wastes from timber, that undergoes mechanical treatment to serve as crucial raw material for producing briquettes, even though delivery of such raw material to the companies is possible for the purpose of making wood pellets and as well as briquettes. Use of wastes from wood as the raw material from the secondary sources, leads to obtaining raw material to begin manufacturing of wood briquettes and thus, all masses of wood that have not been exploited is now important for additional production. The importance is depicted in several aspect

Table 9. Comparative Review of Calorific Power of Certain Fuels[16]

Type of Fuel	Weight (kg/m^3)	Humidity (%)	Quantity of Ash (%)	Caloric Value MWh/Mt
Briquette	550-650	10	0.4-0.6	4.65-4.75
Pellet	600-700	9	0.6-0.8	4.75-4.85
Sawdust	cca 200	8	0.4-0.6	4.80-4.90
Wood chips	250-350	50	0.4-3.0	2.25-2.35
Distilled oil	830	0	0	9.90
Coal	830	5	3-5	9.90

in particular economic, due to the production of organic goods in the wood industry, whereby wood processor-manufacturer is not supposed to be having a briquetting plant, though they do a delivery of the starting material to different manufacturers in order to receive sufficient compensation.

Even though there are the advantages of producing and using the wood briquettes and pellets, the sector that deals with creating and utilizing wood waste is faced with problems in Ghana. The problems are as a result of overutilization of timber, insufficient knowledge of the advance technologies used in the exploitation of the wood waste, absence of the market to sell the products manufactured out of the wood waste, environmental pollution from waste categorised as primary and secondary in nature, failure to apply legislations in management and conservation of the forests, lack of regulations on environment to governs the way in wastes are disposed on the land and harmful gases which are being emitted to the atmosphere, inadequate incentives for production and applications of fuels from renewable energy sources and the low level of awareness on the importance of using renewable energy such as bio-fuel.

4.1 Recommendations

The paper therefore puts forward the following recommendations as a way of solving the problem faced by the sector dealing with creating and utilizing wood waste.

1. Planting of 20 million trees annually by the Government through Forest Commission initiative in schools and other public institutions as part of the campaign to avert serious loss of forest and provide sources of raw material for wood industry.

2. Building at least one new industry after every five years for sustainable production of wood products in regions with highest forest cover in Ghana.

3. New technologies should be introduced to assist in reduction of pollution to the environment, and to enhance employment opportunities in the forest and wood production industry among huge number of jobless rural dwellers.

4. The Government of Ghana through the Ministry of Land, Environment and Natural Resources in conjunctions with the Ministry of Trade and Industry should create market for the product made out of waste wood which will encourage use of renewable sources of energy.

5. The Government of Ghana should enact proper legislations and guidelines on harvesting of indigenous trees which are on the verge of extinction, for timber and other purposes.

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Conflicts of Interest
The authors declared no conflict of interest.

Author Contribution
The authors confirm contribution to the paper as follows: study conception: Takase M, Kipkoech R, Kibet J, and Mugah F. Draft manuscript preparation: Takase M, Kipkoech R, Kibet J, and Mugah F. All authors reviewed and approved the final version of the manuscript.

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