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Exploring the Fiscal of Wood-Based Renewable Biomass as an Energy Source

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Abstract

In Nigeria, the adoption of sustainable biomass for energy generation is rising. Moisture content significantly impacts biomass utilization efficiency. This study investigates the economic impact of moisture at different stages of the wood biomass distribution chain. The methodology includes a literature review, interviews, and economic calculations. The costs associated with moisture content in Nigeria amount to approximately ₦500,000,000 (Five Hundred Million Naira). Utilizing wood biomass with a moisture content of 32% weight, as opposed to 18% weight, is more costly. Transportation contributes significantly to this increase, while reduced burning efficiency accounts for the remaining half. Higher moisture content increases transportation costs due to additional weight and volume, leading to increased fuel consumption and expenses. Decreased burning efficiency reduces energy output and increases fuel consumption, impacting economic viability. Planned air drying of wood biomass can reduce transportation expenses and improve combustion efficiency. Large-scale power plants prefer wood biomass with 18-36% moisture content by weight. Air drying reduces moisture content, decreasing transportation costs and improving combustion characteristics.

Keyword: Biomass, Wood, Energy, Renewable, Sustainable, Fuel.

Introduction

The quest for sustainable energy sources has propelled wood-based renewable biomass into the spotlight (Abbasi & Abbasi, 2010; Demirbas, 2004). As a carbon-neutral energy source, biomass offers a promising alternative to fossil fuels, contributing to energy security and rural development (FAO, 2008; IEA, 2020). Wood biomass, in particular, has gained attention for its abundance, renewability, and potential to reduce greenhouse gas emissions (Gossling & Peeters, 2007; Jenkins et al., 1998). The development of bioenergy systems is driven by the need to reduce greenhouse gas emissions and promote sustainable energy production (Kumar et al., 2008; McLoughlin & Smeets, 2003). However, the evaluation of bioenergy systems is complex and requires careful consideration of multiple factors, including energy production, environmental impact, and economic viability (Mitchell, 2000) The utilization of wood-based renewable biomass as an energy source has gained significant attention in recent years, driven by the need to reduce greenhouse gas emissions and promote sustainable energy production (Nair, 1993; Parikka, 2004). Biomass energy can contribute to energy security, rural development, and climate change mitigation (Ragauskas et al., 2006; Saidur et al., 2011). Wood biomass, in particular, is a promising energy source due to its abundance, renewability, and potential to reduce greenhouse gas emissions (Smeets & Faaij, 2007).

The development of bioenergy systems is complex and requires careful consideration of multiple factors, including energy production, environmental impact, and economic viability (Mitchell, 2000). The evaluation of bioenergy systems involves assessing the entire supply chain, from biomass production to energy conversion and utilization (Kumar et al., 2008). This requires a comprehensive approach that considers technical, economic, environmental, and social aspects (McLoughlin & Smeets, 2003). Agroforestry systems, which integrate trees into agricultural landscapes, can provide a sustainable source of biomass for energy production (Nair, 1993). These systems can also contribute to biodiversity conservation, soil improvement, and climate change mitigation (Gossling & Peeters, 2007). However, the development of agroforestry systems for bioenergy production requires careful planning and management to ensure environmental and social sustainability (Smeets & Faaij, 2007). The global biomass fuel resource is vast, with an estimated annual production of 220 billion oven-dry tons (Parikka, 2004). However, the technical and economic potential of biomass energy is limited by factors such as land availability, biomass yield, and conversion efficiency (Ragauskas et al., 2006). The development of advanced bioenergy technologies, such as biomass gasification and biochemical conversion, can improve the efficiency and sustainability of biomass energy production (Saidur et al., 2011).

The sustainability of wood biomass energy depends on factors such as forest management practices, biomass harvesting methods, and energy conversion technologies (McLoughlin & Smeets, 2003). Sustainable forest management practices, such as selective logging and reforestation, can maintain forest ecosystem services while providing a sustainable source of biomass (Nair, 1993). Biomass harvesting methods, such as whole-tree harvesting and residue removal, can impact soil fertility and ecosystem biodiversity (Smeets & Faaij, 2007). The development of wood-based renewable biomass energy requires a comprehensive policy framework that considers technical, economic, environmental, and social aspects (Ragauskas et al., 2006). Policy instruments, such as renewable energy targets, tax incentives, and subsidies, can promote the development of bioenergy systems (Saidur et al., 2011). However, policy frameworks must also ensure environmental and social sustainability, including the protection of biodiversity and the rights of local communities (Gossling & Peeters, 2007).In conclusion, the development of wood-based renewable biomass energy requires a comprehensive approach that considers technical, economic, environmental, and social aspects. The sustainability of biomass energy depends on factors such as forest management practices, biomass harvesting methods, and energy conversion technologies. Policy frameworks must promote the development of bioenergy systems while ensuring environmental and social sustainability

The Key Objectives:

1. **Diversify Energy Sources:** One objective is to diversify energy sources by promoting the use of wood-based biomass alongside traditional fossil fuels. This helps reduce dependence on non-renewable energy sources, ensuring a more sustainable and resilient energy mix.
2. **Promote Sustainable Forest Practices:** Another objective is to encourage sustainable forest management practices. This involves promoting responsible harvesting of trees, reforestation efforts, and ensuring the preservation of forest ecosystems. By doing so, we can maintain the long-term availability of wood-based biomass as an energy source.

3. **Improve Energy Efficiency:** An objective is to improve energy efficiency in the conversion of wood-based biomass into usable energy. Research and development efforts should focus on optimizing conversion technologies and processes to maximize energy output while minimizing waste and environmental impacts.
4. **Foster Innovation and Technology:** Encouraging innovation and technological advancements in the biomass energy sector is another objective. This includes developing efficient biomass conversion technologies, exploring new methods for biomass storage and transportation, and finding ways to enhance the overall sustainability and cost-effectiveness of utilizing wood-based biomass.
5. **Ensure Economic Viability:** One of the key objectives is to ensure the economic viability of utilizing wood-based biomass as an energy source. This involves assessing the financial costs and benefits, exploring potential revenue streams, and creating supportive policies and incentives to attract investments and promote the growth of the biomass energy sector.
6. **Align with Sustainable Development Goals (SDGs):** Lastly, a significant objective is to align the exploration of wood-based biomass as an energy source with the SDGs. This includes contributing to climate action (SDG 13), affordable and clean energy (SDG 7), responsible consumption and production (SDG 12), and other relevant goals that promote sustainability and socioeconomic development.

Significance of the Research

1. **Renewable Energy:** Wood-based biomass is a renewable energy source because trees can be replanted and regrown. By utilizing wood-based biomass as an energy source, we can reduce our reliance on fossil fuels, which helps combat climate change and supports SDG 7 (Affordable and Clean Energy).
2. **Carbon Neutrality:** When wood-based biomass is burned for energy, it releases carbon dioxide (CO2) into the atmosphere. However, this CO2 is offset by the regrowth of trees, which absorb CO2 during photosynthesis. Therefore, wood-based biomass can be considered carbon-neutral, contributing to SDG 13 (Climate Action).
3. **Sustainable Forest Management:** The exploration of wood-based biomass encourages sustainable forest management practices. By ensuring that forests are managed responsibly, we can protect biodiversity and ecosystems, contributing to SDG 15 (Life on Land).
4. **Economic Opportunities**: The use of wood-based biomass as an energy source can create new economic opportunities, such as job creation in the forestry and biomass industries. This aligns with SDG 8 (Decent Work and Economic Growth) by promoting sustainable economic development.
5. **Energy Access:** Wood-based biomass can be particularly beneficial in areas with limited access to electricity grids. By utilizing biomass for energy generation, we can provide affordable and reliable energy to remote communities, contributing to SDG 7 (Affordable and Clean Energy) and SDG 1 (No Poverty).

Research Process/Method

Figure 2, the analysis of the steps that was involved in achieving the topic of exploring the fiscal potential of wood-based renewable biomass as an energy source, specifically focusing on literature reviews, interviews, analyses, and calculations, as well as the content on wood-based biofuels in Nigeria:

1. **Literature Reviews:** Conducting thorough literature reviews is an essential step. This involves reviewing existing studies, research papers, and publications related to wood-based biomass as an energy source. The purpose is to gather knowledge and insights on the subject, including the scientific, economic, and environmental aspects. Literature reviews help establish a foundation of knowledge and inform subsequent research and analysis.
2. **Interviews:** Engaging in interviews with relevant stakeholders and experts is crucial. This step involves reaching out to researchers, industry professionals, government officials, and other key individuals involved in the biomass energy sector. Interviews provide valuable firsthand information, perspectives, and insights into the current state and potential of wood-based biofuels in Nigeria. This helps in understanding the practical aspects, challenges, and opportunities associated with the use of wood-based biomass as an energy source in the country.

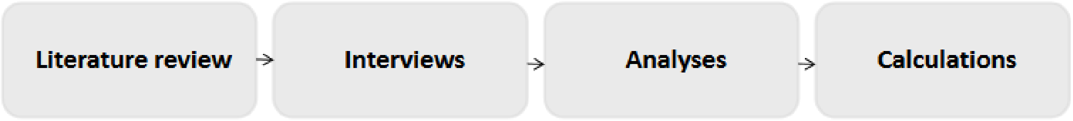

Fig 1: Research Process

3. **Analyses:** Conducting comprehensive analyses is vital for assessing the feasibility and potential benefits of wood-based biofuels in Nigeria. This includes analyzing the availability and sustainability of biomass resources, the existing infrastructure for biomass collection and utilization, and the economic and environmental impacts of using wood-based biofuels compared to traditional energy sources. The Analyses also involve evaluating policy frameworks, market dynamics, and potential barriers to implementation. These analyses help provide a holistic understanding of the opportunities and challenges for wood-based biofuels in Nigeria.
4. **Calculations: The Quantitative** calculations play a crucial role in assessing the fiscal potential of wood-based biofuels. These calculations involve estimating the potential biomass yield, energy conversion efficiency, greenhouse gas emissions reduction, and economic viability of implementing wood-based biofuel projects. Financial calculations, such as cost-benefit analysis and return on investment calculations, also help to determine the fiscal feasibility of utilizing wood-based biofuels in Nigeria.

We consider wood-based biofuels in Nigeria specifically, it becomes important to analyze the country's biomass resources, such as the availability of forestry and agricultural residues, and the potential for sustainable feedstock production. Assessing the existing policy frameworks, market demand, and infrastructure for biofuel production and distribution in Nigeria is also significant.

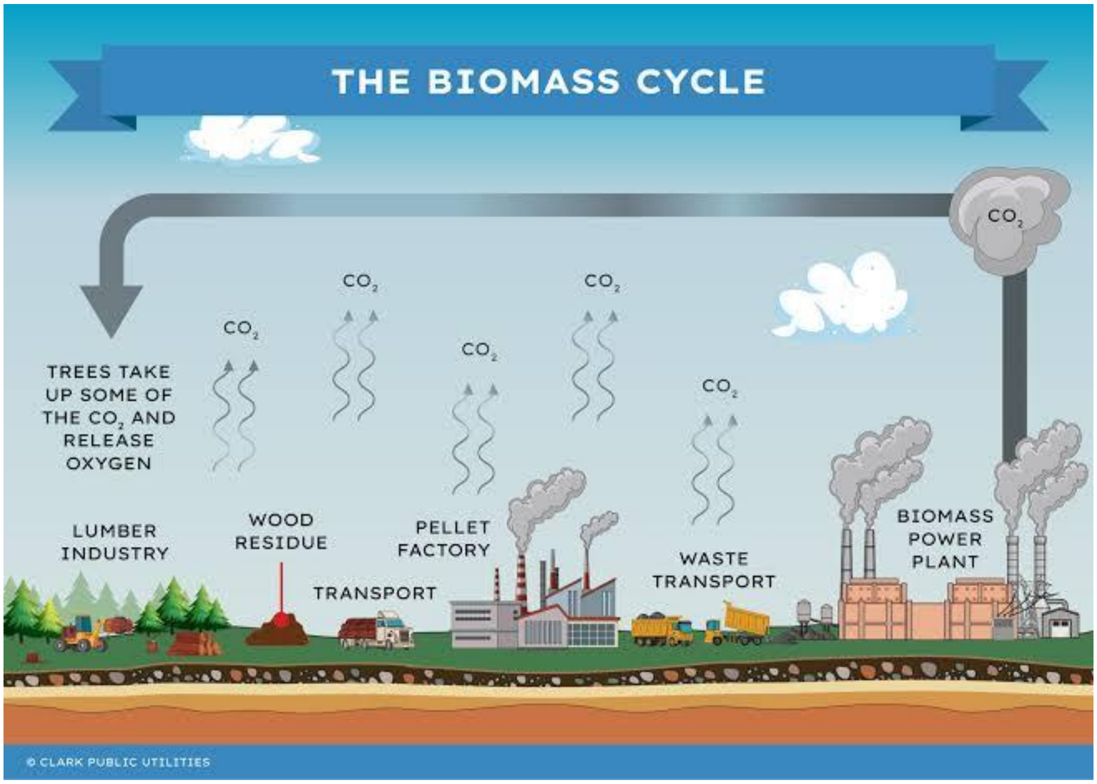

Fig 2: The Biomass Circle

Figure 2: The Biomass Circle This figure represents the concept of a circular economy for biomass. It highlights the cyclical nature of biomass energy, from the initial production of biomass to its conversion into useful energy and the subsequent recycling or reuse of byproducts. The figure emphasizes the importance of closing the loop and maximizing the efficiency of biomass utilization.

The figure the flow of wood-based biomass in a circular fashion, highlighting the various stages and processes involved in utilizing biomass as an energy source. 1. Lumber industry: This refers to the initial stage where trees are harvested and processed for lumber or other wood products. It signifies the starting point of the biomass supply chain. 2. Wood residue: As a byproduct of the lumber industry, wood residues such as sawdust, wood chips, or bark are generated. These residues can be collected and used as a valuable biomass feedstock for further energy production. 3. Transport: This stage represents the transportation of the wood residues from the lumber industry to the next stage in the biomass energy production process, which could be a pellet factory or another type of biomass processing facility. 4. Pellet factory: At the pellet factory, the collected wood residues are processed and transformed into wood pellets. Wood pellets are a densified form of biomass that can be easily transported, stored, and used in various biomass energy systems. 5. Waste transport: This stage illustrates the transportation of any waste or byproducts generated during the wood pellet production process. Proper management of these waste materials is necessary for environmental sustainability. 6. Biomass power plants: These are the facilities where the wood pellets or other biomass feedstock are utilized to generate energy. Biomass power plants can produce electricity, heat, or both through the combustion or conversion of biomass. The mention of trees in the figure serves as a reminder of the environmental benefits of biomass. Trees capture carbon dioxide (CO2) from the atmosphere through the process of photosynthesis and release oxygen. This natural cycle helps to offset the carbon emissions associated with the combustion of biomass, making it a potentially carbon-neutral energy source. In summary, Figure 2 depicts the circular flow of wood-based biomass, starting from the lumber industry and proceeding through the stages of wood residue collection, transport, pellet production, waste management, and utilization in biomass power plants. The inclusion of trees highlights the environmental aspect of biomass, emphasizing its potential to mitigate carbon emissions and contribute to a sustainable energy system.

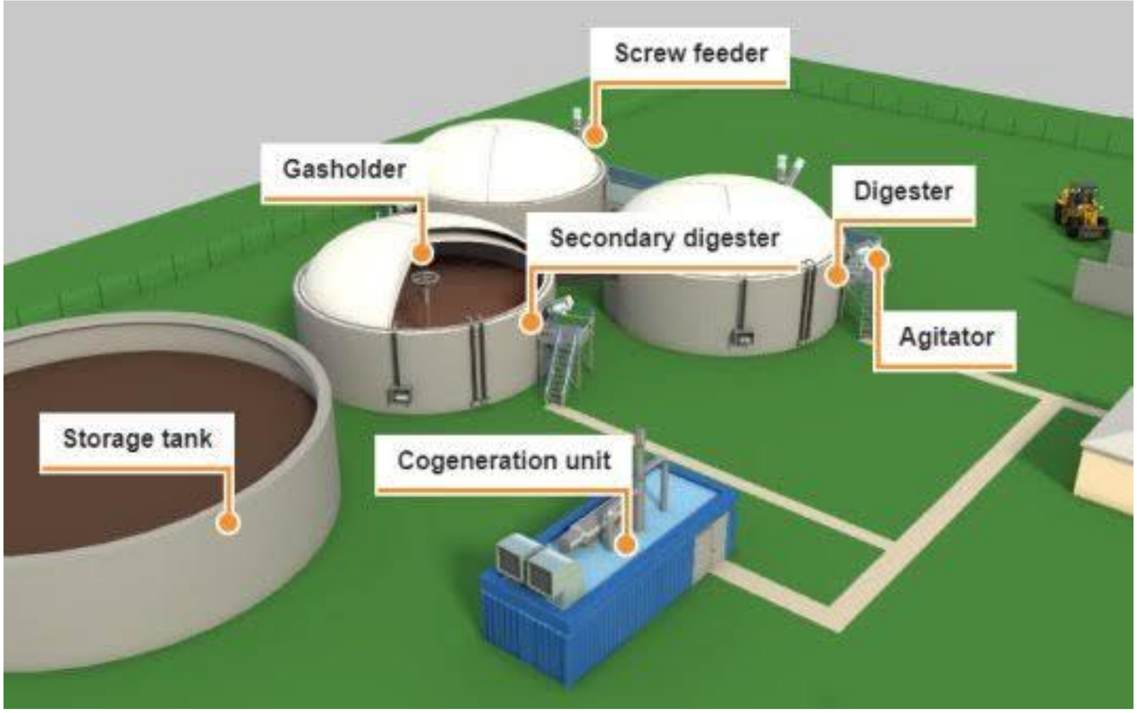

Fig 3: Biomass Energy Plant

Figure 3: Biomass Energy Plant This figure depicts a biomass energy plant, showcasing the various components and processes involved in converting wood-based renewable biomass into energy. It provides a visual representation of the equipment and systems used, such as biomass boilers, turbines, and generators. The figure helps us visualize the infrastructure required for biomass energy production., Figure 3 represents a Biomass Energy Plant. Here's an explanation of the various elements in the figure for easy understanding: 1. Storage Tank: This is a container used to store biomass feedstock, such as wood chips, agricultural residues, or dedicated energy crops. The storage tank ensures a continuous supply of biomass for the energy plant. 2. Gas Holder: The gas holder is a component that stores the biogas produced during the anaerobic digestion process. Biogas is generated by breaking down organic materials in the absence of oxygen and can be used as a fuel for electricity generation or heat production. 3. Screw Feeder: A screw feeder is a device used to deliver biomass feedstock from the storage tank to the anaerobic digester. It ensures a controlled and consistent flow of biomass into the system. 4. Secondary Digester: The secondary digester is a vessel or tank where further digestion of organic matter takes place. It helps to maximize the gas production by providing an additional stage for the breakdown of biomass and the production of biogas. 5. Agitator: An agitator is a mechanical device used to mix and stir the contents within the digester. It helps in maintaining optimal conditions for the anaerobic digestion process by ensuring uniform distribution of biomass and promoting the contact between bacteria and organic matter. 6. Digester: The digester is the main component of the biomass energy plant where the anaerobic digestion process occurs. It is a sealed vessel where organic materials, such as biomass feedstock, undergo decomposition by microorganisms in the absence of oxygen. This process results in the production of biogas, which primarily consists of

methane (CH4) and carbon dioxide (CO2). 7. Cogeneration Unit: A cogeneration unit, also known as a combined heat and power (CHP) system, is an energy conversion system that utilizes the produced biogas to generate both electricity and heat simultaneously. Cogeneration improves overall energy efficiency by utilizing the waste heat generated during electricity generation for other purposes, such as heating or cooling. In summary, Figure 3 illustrates the components and processes involved in a Biomass Energy Plant. It starts with biomass feedstock being stored in a tank and delivered to an anaerobic digester via a screw feeder. The anaerobic digestion takes place in the digester, where organic matter is broken down by microorganisms, resulting in the production of biogas. The biogas is stored in a gas holder before being utilized in a cogeneration unit for the simultaneous generation of electricity and heat.

Results

Chain of Supply for Biomass Fuels Derived from Wood

Based on the findings of this study, it is crucial to assess the moisture content of wood-based biomass at various stages of the supply chain. The typical wood biomass supply chain encompasses the following steps: 1) harvesting, 2) local transportation of wood, 3) local storage and drying of wood, 4) chipping, 5) conveying woodchips to the place of consumption, 6) optional thermal drying, and 7) burning. By evaluating the moisture content at each of these points, stakeholders can effectively manage the economic implications associated with moisture in wood biomass. Optimal moisture management throughout the supply chain plays a vital role in enhancing combustion efficiency, minimizing transportation costs, and maximizing the economic viability of utilizing wood-based biomass for energy generation. Proper harvesting techniques, efficient local transportation, and effective storage and drying methods are essential in reducing moisture content and ensuring the quality of the biomass. Additionally, optional thermal drying can further enhance the combustion efficiency and overall performance of the wood-based biomass. By implementing strategies that address moisture-related challenges, stakeholders can optimize the supply chain and contribute to the sustainable and economically viable use of wood biomass as a renewable energy resource. This is particularly significant in the context of Nigeria's commitment to increasing the utilization of renewable energy sources. Continued research, collaboration among industry experts, and the implementation of best practices are essential for refining and improving the results of the wood biomass supply chain. By doing so, stakeholders can contribute to a more sustainable and efficient energy generation process while maximizing the economic benefits for Nigeria.In addition to the collection of stubs and branches from conventional logging, the biomass of harvested wood may not be sufficient to meet the demands for wood biomass.

As a result, additional measures, such as the distinct thinning of woodlands, may be necessary. The thinning of forests for biomass harvesting not only provides a supplemental source of wood biomass but also brings about a positive side effect—an improvement in the growth of the forests themselves. Thinning involves the selective removal of trees or vegetation to create spacing and reduce competition among trees. This process allows the remaining trees to have access to more resources, including sunlight, water, and nutrients, resulting in improved growth and overall forest health. Thinning also serves as a forest management practice by promoting biodiversity, reducing the risk of forest fires, and enhancing the resilience of the ecosystem. By incorporating the thinning of forests into the biomass harvesting process, stakeholders can ensure a sustainable and balanced approach. This method not only meets the demands for wood biomass but also contributes to the long-term health and productivity of the forests. It aligns with the principles of sustainable forestry management, which seek to maximize the ecological, social, and economic benefits of forest resources. Implementing thinning practices as part of the wood biomass supply chain can have positive environmental impacts while supporting the renewable energy goals of Nigeria. It is essential to consider the specific ecological characteristics of the forests and engage in responsible and well-planned thinning activities to maintain the integrity and biodiversity of the ecosystems. The amount of moisture present during harvesting is unaffected by the harvester's efforts and is always high. Because of this, it is not possible to measure the amount of moisture present throughout the harvesting process.

The cut wood needs to be stacked into manageable sections before it can be transported within the immediate area.

It is not possible to measure the amount of moisture present during motions that are local.

Reducing the amount of moisture in the wood is best accomplished by first storing it locally and then drying it. This stage is quite inexpensive. Once the wood has been collected, it is either hauled, put into larger heaps, and left to air dry for at least three summer months or for an extended period of time overall. These bigger piles are located in areas that are reachable by larger trucks for the purpose of subsequent delivery to a power plant. A tarpaulin is used to cover the huge heaps in order to promote more efficient air drying. Additionally, there must be adequate ventilation below the pile in order for it to be considered complete. The construction of the pile ensures that any precipitation will flow off of it. The moisture content of the wood must be reduced to a point where it can be burned as fuel before this step can be considered complete. However, because there are so many heaps that need to be measured, traditional methods of moisture assessment are not frequently organized. It does not appear that the advantages of measures outweigh the disadvantages. Should the process of air drying be carried out appropriately, the level of moisture is anticipated to be satisfactory.

At the location, there are plans in place to chip wood for local storage and drying. The chipping machine sends the chips straight to the waiting trucks for transport. When it comes to the burning process, one of the most crucial parameters to consider is the moisture level of the wood chips. In addition, a high percentage of moisture contributes to a rise in the needless expenditures of transporting water. During chipping, however, moisture content is often not monitored since it is not relevant to the process.

Transporting wood chips often involves the use of vehicles that have weight-based maximum load constraints of up to 38 tonnes. The capacity of each truck is between 100 and 140 m3. The amount of moisture present has a considerable bearing on the expenses of transportation.

After it has been transported, wood bio-mass may be dried using thermal methods if there is affordable extra energy available. The best time of year to perform this kind of drying is during the summer, when there is a surplus of energy available from various industrial activities. During the colder months, it makes more sense to put this surplus of energy toward heating homes in the surrounding area. However, thermal drying is often not done since the burning procedures are typically optimized to use wood bio-mass with a moderate moisture content. This means that wood bio-mass with a moderate moisture content can be burned.

Burning methods are generally optimized to make use of wood bio-mass that has a moisture content of between 40 and 50 percent. Normal procedures for controlling moisture content involve analyzing samples collected from incoming cargoes of wood chip material. Because the analysis of moisture takes around twelve hours, the feedback mechanism is quite sluggish from the point of view of the burning processes. On the other hand, the creation of quick online measurement systems is now underway.

Analysis of the effects of moisture on the economy

Equation (1) used to determine the fuel value of wood

$$LHVA = LHVD.(1-M)-Hvap.M \qquad (1)$$

Where.

LHV is the lower heating value.

LHVa is the lower heating value on arrival

LHVd is the lower heating value for dry wood.

M is the moisture content on arrival

Hvap is the enthalpy of vaporisation = 2.442MJ/Kg.

The lower heating value (LHV) of a fuel refers to the amount of heat energy released when the fuel undergoes complete combustion. In the context of wood, LHVA represents the lower heating value on arrival, which takes into account the moisture content of the wood when it arrives at its intended destination.

The term LHVD in the equation represents the lower heating value for dry wood. This value refers to the heat energy released when one unit of completely dry wood is burned. Dry wood typically has a very low moisture content, usually around 0-5%

Now, let's focus on the term (1-M) in the equation. M represents the moisture content on arrival, expressed as a percentage. When wood is harvested or transported, it often contains a certain amount of moisture. The term (1-M) calculates the dry weight fraction of the wood. For example, if the moisture content is 10%, the dry weight fraction would be 1 - 0.10 = 0.90, indicating that 90% of the weight of the wood consists of dry material

The second part of the equation involves the enthalpy of vaporization (Hvap). This term represents the amount of heat energy required to convert one kilogram of water into vapor. In the context of wood, it signifies the heat energy needed to evaporate the moisture present in the wood. The value 2.442 MJ/kg is the specific enthalpy of vaporization for water, which is a constant value.

Multiplying the enthalpy of vaporization (Hvap) by the moisture content (M) gives the heat energy required to vaporize the moisture in the wood. By subtracting this from the lower heating value for dry wood (LHVD), the equation accounts for the heat loss due to the evaporation of moisture during combustion.

In summary, equation (1) allows for the adjustment of the lower heating value of wood by considering the moisture content. It calculates the lower heating value on arrival (LHVA) by subtracting the heat energy required to evaporate the moisture from the lower heating value for dry wood (LHVD). This equation is important for accurately assessing the fuel value and energy potential of wood as it takes into account the moisture content, which can significantly affect the available heat energy during combustion.

In actuality, the elements of wood that burn are coal and hydrogen. In the same way that the moisture absorbed in the input wood results in a lower overall efficiency when hydrogen burns, water is produced when hydrogen burns. This requires energy for vaporization. A common value is LHV D = 19.4 MJ/kg, according to Johnic green renewable energy. The computations employ this value, which takes into account this phenomenon.

Table 1 summarizes how moisture affects the actual fuel value of wood. Equation (1) has been used to calculate the values in Table 1 in the manner previously indicated. The term well-dried" refers to wood with a moisture content of less than 30 w-%.

The relationship between moisture content, expressed as a percentage of the total weight (W-%), and the lower heating value (LHVa) of the fuel in terms of mega-joules per kilogram (MJ/Kg). The table shows the progressive decrease in fuel value as moisture content increases. At a moisture content of 30% (W-%), the fuel's lower heating value is 14.9 MJ/Kg (LHVa). This indicates that for every kilogram of fuel, there is a release of 14.9 mega-joules of energy when combusted. As the moisture content increases to 35% (W-%), the lower heating value decreases to 13.8 MJ/Kg (LHVa), representing a reduction in fuel value. At 40% (W-%) moisture content, the lower heating value further decreases to 12.8 MJ/Kg (LHVa). This reduction in energy content is attributed to the presence of additional moisture, which requires energy to evaporate during combustion, consequently reducing the available energy released. As moisture content continues to rise to 45% (W-%), the lower heating value decreases to 11.7 MJ/Kg (LHVa). The increased moisture content leads to a further decrease in the available energy content of the fuel, making it less efficient and valuable for energy generation. When the moisture content reaches 50% (W-%), the lower heating value drops to 10.6 MJ/Kg (LHVa). This substantial decrease in energy content highlights the significant impact that moisture has on the overall fuel value. Higher moisture content not only reduces the available energy but also increases the energy required for moisture evaporation during combustion. At the highest moisture content in the table, 55% (W-%), the lower heating value is reduced to 9.5 MJ/Kg (LHVa). This emphasizes the substantial negative effect of excessive moisture on the fuel's energy content. As moisture content increases, the energy potential of the fuel diminishes significantly, thereby impacting its efficiency and overall value as an energy source. This table's results illustrate the importance of minimizing moisture content in fuel sources to maximize energy efficiency. By ensuring lower moisture levels, the available energy content of the fuel can be preserved, leading to more effective and efficient energy generation processes.

Table 1: Moisture's detrimental effect on fuel value

W-%(Moisture)	MJ/Kg(LHVa)
30	14.9
35	13.8
40	12.8
45	11.7
50	10.6
55	9.5

Table 2 provides an estimate of the number of truckloads of wood chips needed to produce the 30 000 GWh/a for wood bio-mass that is the national energy production objective. The calculations take into account the fuel values (LHV A) for biomass made from wood at various moisture percentages, as shown in Table 1. The calculations make use of a 40-ton weight assumption for a truck load. The quantity of additional dry wood needed to offset the detrimental effects of moisture is referred to as "additional wood%." The additional truck loads needed to deliver the extra timber are the additional loads. Using equation (2), one may determine how many truck loads are necessary.

The quantity of truck loads may be calculated by dividing the total energy capacity of 25,000 gigawatt-hours (GWh) by the lower heating value of the fuel (LHVA) converted to mega-joules per megawatt-hour (MJ/MWh), and then dividing that by 3.6

$LHVA = GWh\left(M_j/Mwh\right)$(2)

Table 2 showcases the relationship between moisture content, expressed as a percentage of the total weight (W-%), the additional percentage of wood required (% Additional -wood), the number of truck loads required (# Loads of truck), and the percentage increase in the number of truck loads (% Additional truck loads). At a moisture content of 30% (W-%) and no additional wood required, the table indicates that 194,467 truck loads are necessary. This serves as the baseline for comparison as moisture content increases and additional wood is introduced. As the moisture content rises to 35% (W-%), a 1% increase in additional wood is necessary. This leads to 210,148 truck loads, representing a 9% increase compared to the baseline. When the moisture content reaches 40% (W-%), a 4% increase in additional wood is required. Consequently, the number of truck loads increases to 219,741, representing a 20% increase compared to the baseline. At 45% (W-%) moisture content, an additional 6% of wood is needed, resulting in 251,142 truck loads. This represents a 32% increase in the number of truck loads compared to the baseline. When the moisture content reaches 50% (W-%), an additional 8% of wood is required. This leads to a substantial increase in the number of truck loads, totaling 278,654. The percentage increase in the number of truck loads compared to the baseline is 47%. At the highest moisture content in the table, 55% (W-%), an additional 10% of wood is needed. Consequently, the number of truck loads required increases to 304,252, representing a 65% increase compared to the baseline. The data in Table 2 demonstrates the significant impact of moisture content on the quantity of wood and corresponding truck loads required. As moisture content increases, the additional wood needed to compensate for the moisture also increases, resulting in a higher number of truck loads. This emphasizes the importance of managing moisture levels to optimize transportation and logistics efficiency. Proper moisture control can help minimize the additional wood needed and subsequently reduce the number of truck loads, leading to potential cost savings and improved transportation logistics for wood-based biomass

Table 2: The Impact of Moisture in determining the Quantity of Truck Loads Necessitate

W-%(Moisture)	%(Additional -wood)	#(loads of truck)	%(additional truck of loads)
30	0	194 467	0
35	1	210 148	9
40	4	219741	20
45	6	251142	32
50	8	278 654	47
55	10	304 252	65

Table 3 showcases the incremental yearly transportation expenses required to meet the country's energy output target due to elevated moisture levels in wood biomass. It is important to note that, according to Johnic Green Renewable Energy (2022), a 40-ton truck typically receives a compensation of #2,000 /km. Assuming an average transit route of 80 km, the cost of a truckload would amount to 2 * 80 km * #2000/km, resulting in a total of #320,000,00. By considering these transportation costs in relation to the moisture content of the wood biomass, stakeholders can better understand the economic implications and plan accordingly. Optimal moisture management throughout the supply chain can minimize these additional expenses and contribute to the overall efficiency and cost-effectiveness of utilizing wood biomass for energy generation. It is worth mentioning that while this example illustrates the cost calculation for a truckload, additional factors such as the number of truckloads required and the specific transportation logistics need to be considered for a comprehensive analysis. These considerations will aid in developing strategies to optimize transportation costs and improve the economic viability of wood biomass as a renewable energy resource.

Table 3 further provides insights into the price of additional raw materials required to compensate for moisture and meet the country's energy production targets. The estimates presented in the table are based on a pricing level of #20,000,00 /MWh for raw materials. To calculate the extra expenditure for raw materials, equation (3) can be utilized, taking into account the moisture content and its impact on energy production. By factoring in the costs associated with obtaining additional raw materials, stakeholders can gain a comprehensive understanding of the economic implications of moisture in wood biomass. This analysis allows for informed decision-making and the development of strategies to optimize raw material procurement and minimize expenses. It's important to note that equation (3) provides a tool for estimating the extra expenditure, but specific calculations may vary depending on the unique circumstances of each situation. By utilizing this equation alongside Table 3, stakeholders can accurately assess the financial impact of moisture content and devise effective approaches to achieve the country's energy production targets efficiently.

$$\text{Additional cost} = \text{National goal} / \text{LHV}_A * \text{Additional wood \%} * \text{Price level} \quad (3)$$

Additional cost: Additional cost for raw material National goal: 30,,000 GWh LHVA: The lower heating value on arrival (fuel value) Additional wood %: Additional dry wood required (from Table 2) Price level: #20,000.00/MWh"

1. **Additional cost**: This refers to the extra expense incurred for obtaining the raw materials used in the production of wood-based renewable biomass. These costs can include factors such as harvesting, processing, transportation, and other related expenses.
2. **National goal:** The stated national goal of 30,000 GWh represents the target amount of energy that authorities aim to generate using wood-based renewable biomass. GWh stands for gigawatt-hours, which is a unit of electrical energy.
3. **LHVA:** LHVA stands for the lower heating value on arrival, which is a measure of the energy content or fuel value of the wood-based renewable biomass when it is received or delivered. This value indicates how much heat energy can be obtained from a given quantity of the biomass.
4. **Additional wood %:** This refers to the percentage of additional dry wood required to meet the energy demands specified in Table 2. The exact values for this percentage would need to be referred to in the mentioned table.
5. **Price level:** The price level of #20,000.00/MWh indicates the cost of producing or purchasing 1 megawatt-hour (MWh) of energy generated from wood-based renewable biomass. This cost includes factors such as production, maintenance, distribution, and other associated expenses. In conclusion, the sentence you provided highlights various aspects related to the fiscal analysis of using wood-based renewable biomass as an energy source. It touches on additional costs, the national energy generation goal, fuel value, additional wood requirements, and the price level associated with producing or purchasing energy from this renewable source..

Table 3: Additional Annual Transportation Costs & Additional Cost for Raw Materials

Moisture W-%	**Additional transportation cost**	**Additional cost for raw materials**	**Total Additional cost**
30	0	0	0
35	6	7	13
40	12	15	27
45	19	24	43
50	27	34	63
55	39	49	88

Table 3 displays the relationship between moisture content, expressed as a percentage of the total weight (W-%), the additional transportation costs, the additional cost for raw materials, and the total additional cost. At a moisture content of 30% (W-%), there are no additional transportation costs or additional costs for raw materials, resulting in a total additional cost of 0. As the moisture content increases to 35% (W-%), there is a 6% increase in transportation costs and a corresponding 7% increase in raw material costs. The total additional cost amounts to 13. At 40% (W-%) moisture content, the additional transportation costs rise to 12%, while the additional cost for raw materials increases to 15%. The total additional cost reaches 27. When the moisture content reaches 45% (W-%), the additional transportation costs rise further to 19%, and the additional cost for raw materials increases to 24%. This leads to a total additional cost of 43. At 50% (W-%) moisture content, the additional transportation costs increase to 27%, and the additional cost for raw materials rises to 34%. The total additional cost reaches 63. At the highest moisture content in the table, 55% (W-%), there is a substantial increase in both the additional transportation costs and the additional cost for raw materials. The transportation costs rise to 39%, while the cost for raw materials increases to 49%. The total additional cost reaches 88.

The data in Table 3 demonstrates the impact of moisture content on transportation costs and raw material costs. As the moisture content increases, the additional transportation costs and the cost for raw materials also increase, resulting in a higher total additional cost. Proper moisture control is essential to minimize these additional costs. By reducing moisture content, transportation costs can be optimized due to the decreased weight and volume of the material. Moreover, lower moisture content reduces the need for additional raw materials, which can help lower costs and improve overall economic efficiency. Understanding and managing moisture content in the supply chain is crucial for minimizing additional costs associated with transportation and raw materials. By implementing effective moisture control strategies, such as proper drying techniques and storage practices, businesses can mitigate these additional expenses and improve their overall financial performance.

The actual amount of moisture ranges from 35 to 50 percentage percent. According to Table 3, the total extra expenditures for moisture content of 50 w% are 55 M more than those for 35 w%. The largest potential effect of moisture in Nigeria is 55 M. Using the market price of 20,000,00/MWh for wood bio-mass, the market value for the national target of 30 000 GWh is 500 M. The calculations therefore demonstrate that, contrary to popular belief, the importance of moisture is only 10% of the overall market value of wood biomass.

Moisture measurement is crucial for process optimization since raw material moisture content affects burning. It would be beneficial to develop measurement methods that would make it possible to monitor moisture levels in real time. There are many actors involved in the supply chain. The cost of raw materials among actors depends on the amount of moisture of the wood.

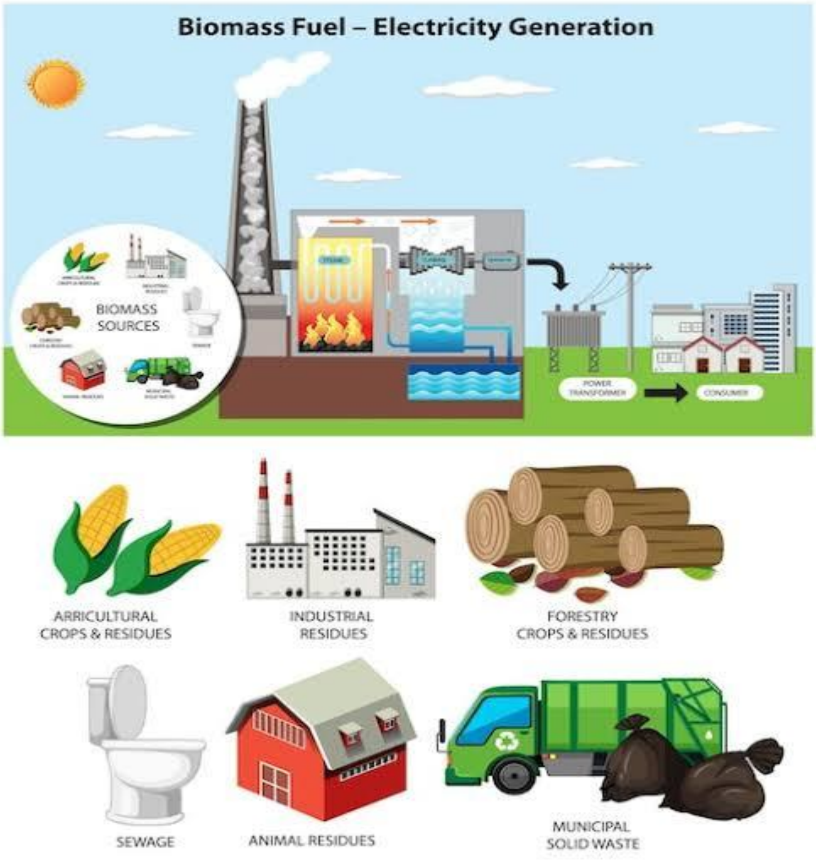

Fig 4: Biomass Energy

Fig 5: The Biomass Gasification power plant System

The figure represents the components and processes involved in a biomass gasification power plant system, which converts biomass into syngas (synthetic gas) that can be used to generate electricity or heat. 1. Boiler: The boiler is a crucial component where the biomass feedstock, such as wood chips or agricultural residues, is combusted or burned. It produces heat that is used to generate steam. 2. Syngas Ignition Chamber: The syngas ignition chamber is where the syngas produced from biomass gasification is ignited and burned. This combustion process releases thermal energy. 3. Economizer: The economizer is a heat exchanger that recovers waste heat from the flue gas. It preheats the feedwater or air, improving the overall energy efficiency of the system. 4. 2 Gasifiers: Gasifiers are reactors where the biomass feedstock is converted into syngas through a thermochemical process called gasification. Gasification involves subjecting the biomass to high temperatures and limited oxygen supply to produce a mixture of combustible gases, primarily carbon monoxide (CO) and hydrogen (H2), along with other trace gases. 5. Stack: The stack, also known as a chimney, is a vertical structure that releases the exhaust gases and smoke from the combustion process safely into the atmosphere. 6. ESP (Electrostatic Precipitator): The electrostatic precipitator is an emission control device that removes particulate matter or fly ash from the flue gas. It helps reduce air pollution and ensures compliance with environmental regulations. 7. Syngas: Syngas refers to the mixture of gases, primarily carbon monoxide (CO) and hydrogen (H2), produced during biomass gasification. It is a valuable energy source for power generation or other industrial processes. 8. Fuel Handling System: The fuel handling system is responsible for the storage, handling, and delivery of the biomass feedstock to the gasifiers. It ensures a consistent and controlled supply of biomass for the gasification process. In summary, Figure 5 illustrates the key elements of a biomass gasification power plant system. It includes components such as the boiler, syngas ignition chamber, economizer, gasifiers, stack, ESP, and fuel handling system. The system converts biomass into syngas through the gasification process, which is then utilized for power generation, producing electricity or heat.

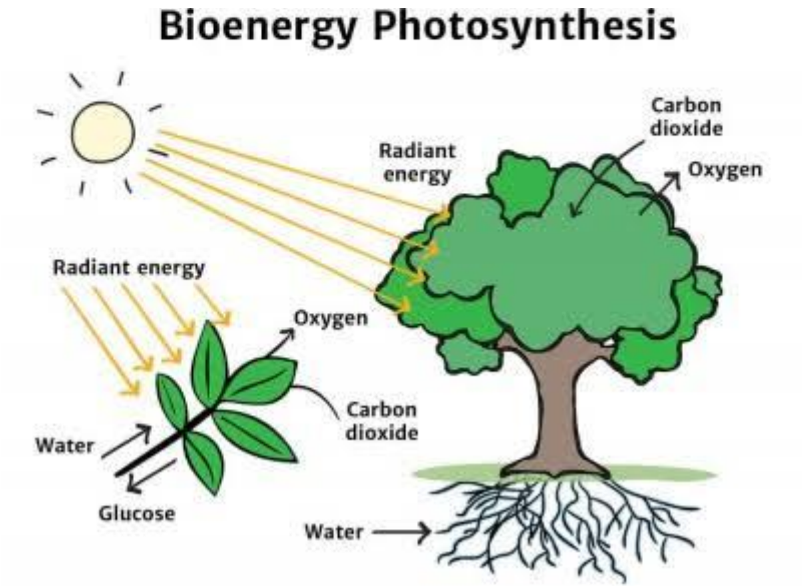

Fig 6: Biomass the Knowledge Bank Solar

The figure represents the interconnected processes and components involved in the generation of biomass through solar energy, specifically focusing on the relationship between bioenergy, photosynthesis, and key elements such as water, glucose, radiant energy, carbon dioxide (CO2), and oxygen. 1. Bioenergy: Bioenergy refers to the energy derived from biomass, which is organic matter such as plants, crops, or agricultural residues. Biomass can be converted into biofuels or used directly for various energy purposes. 2. Photosynthesis: Photosynthesis is the process by which green plants, algae, and some bacteria convert radiant energy from the sun into chemical energy. It occurs in the presence of chlorophyll and involves the absorption of carbon dioxide (CO2) and the release of oxygen (O2). 3. Water: Water is one of the essential components for photosynthesis. It is absorbed by plants through their roots and transported to the leaves, where it plays a crucial role in the conversion of radiant energy into chemical energy. 4. Glucose: Glucose is a simple sugar produced during photosynthesis. It serves as a primary source of energy for plants and is utilized in various metabolic processes. 5. Radiant energy: Radiant energy refers to the energy carried by electromagnetic waves, particularly in the form of sunlight. It is the primary source of energy for photosynthesis, driving the conversion of carbon dioxide and water into glucose and oxygen. 6. Carbon dioxide (CO2): Carbon dioxide is a gas present in the atmosphere and is crucial for photosynthesis. Plants absorb carbon dioxide and use it as a raw material in the process of converting radiant energy into chemical energy. 7. Oxygen: Oxygen is a byproduct of photosynthesis and is released into the atmosphere. It plays a critical role in supporting life and serves as the primary component for respiration. In summary, Figure 6 illustrates the relationship between solar energy, bioenergy, and photosynthesis. It highlights the key elements involved, including water, glucose, radiant energy from the sun, carbon dioxide, and oxygen. Photosynthesis, driven by radiant energy, converts carbon dioxide and water into glucose and oxygen, which contributes to the biomass formation. The understanding of these processes is essential in harnessing solar energy and utilizing biomass as a renewable and sustainable source of energy

Conclusion

Nigeria's commitment to wood biomass utilization aligns with global renewable energy efforts. Moisture content significantly impacts combustion efficiency and transportation feasibility. This study examines the economic impact of moisture throughout the wood biomass supply chain. Managing moisture content effectively is crucial for economic viability. Planned air drying is a cost-effective solution to reduce transportation expenses and enhance combustion efficiency. Large-scale power plants can benefit from utilizing air-dried wood biomass with 18-36% moisture content by weight. The findings reveal that utilizing wood biomass with 45% moisture content instead of 30% results in a $50 million increase in yearly expenditures. Transportation costs and reduced burning efficiency contribute to this rise. Optimizing moisture management strategies, such as advanced drying techniques, can mitigate these economic challenges. The overall market value of wood biomass will be $500 million when Nigeria reaches its bioenergy objective. Moisture management is crucial, but its impact is relatively small (10% of market value). Continuous monitoring and optimization of moisture content can enhance combustion efficiency.

Conflicts of Interest

The Authors declare that they have no conflict of interest.

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