**BAMBOO BIOMASS: SPRING OF GREEN ENERGY**

 Syed Ali **\*,** Vasudev. L

Department of Forestry and Environmental Science

College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka

\*Corresponding Author Email: *syedalipeer511@gmail.com*

**Abstract**

The major global challenge is to meet the increasing energy requirement and mitigation of climate change for overall functioning of society. This makes a strong need to find alternative energy source for fossil fuels. A strong potential replacement for fossil fuels is bamboo biomass energy. Bamboo biomass can be processed in a variety of methods (thermal or biochemical conversion) to provide a range of energy products (charcoal, syngas, and biofuels), which can be used to replace current fossil fuel products. This chapter mainly focus on potential of Bamboo biomass as rich source of green energy, its desirable properties to utilize as bioenergy and various bamboo biomass energy production techniques such as direct combustion, pyrolysis, gasification and biochemical conversion. Development and utilization of green energy from bamboo biomass not only meet the global energy demand but also play a major role in mitigating climate change and global warming. Thus, to achieve this, complete analysis on Bamboo biomass production, conversion and utilization techniques is required to make use of this rich green energy source for long term economic and environmental stability and future sustainability.

**Keywords**: Bamboo biomass, green energy, climate change, biofuels,

1. **Introduction**

Countries were requested to submit aggressive emission plans regarding reduction targets for 2030 that would be consistent with reaching zero emissions by 2050 during the climate summit "Conference of the Parties COP26" in Glasgow in 2021 [1]. More than 90 nations made commitments to reduce greenhouse gas emissions and stop deforestation by 2030 during the summit, according to reports, and the globe is on an irreversible route to a low-carbon future. More nations declaring carbon neutrality is thus a success. Creating markets for cutting-edge technologies and promoting a financial shift that would assist developing nations in becoming carbon neutral is equally crucial. For the purpose of assisting low- and middle-income countries (LMICs) in coping with negative climatic effects, wealthier nations have pledged to double investment, or adaptation finance [2,3].

About 13 % of the world's primary energy supply and 70 % of the world's renewable energy consumption come from bioenergy, which is mostly utilized to produce heat, power, and transportation fuel. Biomass accounts for 96% of all renewable energy sources in Africa, 65 % in Asia, 59 % in the Americas, and 59 % in Europe. Biomass is mostly utilized for cooking and heating in underdeveloped nations. About 56 EJ of biomass was used for bioenergy in 2017, primarily for heating purposes. Of this amount, 86 % came from primary solid biofuels (such as wood chips, wood pellets, fuelwood, and charcoal), 7% came from liquid fuels, and 2-3% came from biogas [4]. For the long term, bioenergy is essential to achieving strict climate mitigation goals. By 2050, the primary bioenergy energy supply is expected to need to expand by about 138 EJ/year making up about 23% of the world's primary energy supply [5]. Both now and in the future, there will be a greater need for new biomass supply chains and a greater role for international biomass commerce due to the rising global demand and bioenergy production goals. As a bioenergy resource, bamboo can help with the implementation of contemporary biomass solutions in the form of solid (such as chips, pellets, briquettes and charcoal), liquid and gaseous fuels for heating, electricity generation and transportation applications.

Bamboo biomass energy has enormous potential as a fossil fuel substitute. Bamboo biomass can be processed in a variety of methods (thermal or biochemical conversion) to create a variety of energy products (charcoal, syngas, and biofuels), which can be used to replace currently available fossil fuel products. Humans have been cultivating and using bamboo for a variety of reasons for thousands of years. Strong, lightweight, and flexible bamboo stems make it an ideal building material. Paper, textiles, and board are all made from bamboo fibers. Bamboo shoots of a few species are used as food in various Asian nations. A new application for bamboo has been added to the list in recent years as a result of the need to develop alternate energy sources to replace fossil fuel, which is becoming scarce. It involves using bamboo biomass as a source to create various types of energy, such as electricity and biofuels. In the Global South, bamboo is a plentiful resource. Millions of tonnes of bamboo resources are still not being fully used. Millions of hectares of degraded and potentially available land are also ideal for the creation of new plantations. About 50 Mt/year of bamboo might be produced and contribute to the diversification of the biomass feedstock portfolio if 10% of the projected present global bamboo resources could be economically exploited. Due to the fact that some countries that produce bamboo, such as Colombia, Brazil, Indonesia, Nigeria, and South Africa, also export fuels, such as coal and biofuels, bamboo biofuels present these nations with a chance to build new supply chains in support of the ongoing transition from the trade of fossil fuels to that of biofuels [6]. Sustainable bamboo production methods can directly aid in combating climate change and meeting the UN Sustainable Development Goals [7].

1. **Properties of Bamboo as a rich source of biomass**
2. **Physiological Properties**

Bamboo belongs to the subfamily Bambusoideae of the family Poaceae, which includes 1250 species and is classified as a grass. Despite being grass, they have a "woody stem" or culm that can grow to a height of 15-20 metres or even 40 metres in the case of the biggest species known (*Dendrocalamus giganteus*). Bamboo can be harvested in around 3–4 years as opposed to 10–20 years for most softwood. It is one of the most well-known biomass resources due to its high biomass productivity, capacity for self-regeneration, tolerance of poor soils, and ability to grow on degraded land. Bamboo typically grows in warm, humid climates with average annual temperatures of 15-20 °C and yearly precipitation of 1000–1500 mm [8].

Another physiological trait of bamboo is its very irregular flowering, which occurs only every 60 to 120 years or so in most species. Normally, the population of plants will all flower at the same moment, and then each plant will then pass away. The commercialization of many species has been hampered by this phenomenon, known as "mass flowering." As a result of infrequently flowering, bamboo plantations are often grown from vegetative material rather than from seedlings.

1. **Fuel Properties**

Bamboo has several favorable fuel properties, including a low ash content and alkali index. In comparison to other types of biomasses, bamboo biomass has a considerably higher heating value, making it a viable option for direct burning (for instance, co-combustion in thermal power plants). Similar to rice husk and rice straw, but much less so than bagasse and maize stalk, bamboo also contains moisture. The low moisture content reduces the energy required to dry the biomass, increasing utilization effectiveness. The table 1 below provides the fuel characteristic of several biomass feedstocks.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type of biomass** | **Moisture %** | **Ash %** | **Volatile matter %** | **Fixed carbon %** | **Higher heating value kJ/kg** |
| **Rice husk** | 12.05 | 12.73 | 56.98 | 18.88 | 14.638 |
| **Rice straw** | 10.12 | 10.42 | 60.87 | 18.80 | 13.275 |
| **Bagasse** | 50.76 | 1.75 | 41.99 | 5.86 | 9.664 |
| **Palm shell** | 12.12 | 3.66 | 68.31 | 16.30 | 18.446 |
| **Corncob** | 40.11 | 0.95 | 45.55 | 13.68 | 11.198 |
| **Corn stalk** | 41.69 | 3.80 | 46.98 | 8.14 | 11.634 |
| **Bamboo (*Bambusa deecheyama*)** | 14.30 | 3.70 | 63.10 | 18.90 | 15.700 |
| **Bamboo (*Dendrocalamus asper*)** | 5.80 | 2.70 | 71.70 | 19.80 | 17.585 |

Table 1: Properties of different biomass feedstocks [9]

1. **Yield and Productivity**

If bamboo is planted in an area with ideal conditions and is properly managed, it can produce a maximum yield of around 50,000 kg/ha/year [10].

1. **Bamboo biomass energy production techniques**

****Bamboo biomass can be processed in a variety of ways to extract energy, and each method yields a unique end product with a variety of applications. Two basic methods—thermochemical conversion and biochemical conversion—can be used to produce energy from bamboo biomass. The bio-matters in bamboo biomass, which are primarily made of cellulose, are converted into different products using heat in the earlier techniques. Microorganisms can convert biomass into biogas or biofuel through biochemical processes. Below is a schematic representation of the conversion of bioenergy.

Figure 1 : Main bioenergy conversion routes [11]

1. **Direct combustion**

Dry bamboo biomass can be used as firewood to create heat in homes for heating, boiling water, and cooking. It is a reliable energy source for persons living in rural areas without access to electricity. On a large scale, direct combustion of bamboo biomass is also employed in other industrial settings, such as co-generation to produce heat and power in thermal power plants that produce electricity, or in factories making cement or steel. Through co-generation, it is feasible to decrease the amount of fossil fuel used in these facilities. The technical basis of combustion is quite straightforward. It entails carefully regulated combustion of any fuel containing carbon and hydrogen atoms. Carbon dioxide (CO2) and water (H2O) are byproducts of combustion. Most combustion occurs inside a chamber, then a heat exchanger is used to transfer the heat from the hot gas stream to another fluid (typically water or air). After that, this fluid can be used to generate electricity via a turbine or engine. Boilers are heat exchangers that use combustion to heat water. Large-scale steam generation at medium and high pressure (>20 bar) is accomplished using water boilers [12]. In order to maximise the amount of energy recovered and to minimise the production of tars and the emission of non-oxidized gases like carbon monoxide (CO) and volatile organic compounds (VOC), combustion control is necessary to burn out the biomass completely [12]. The quality and distribution of the biomass, as well as the distribution of air and temperature, all have an impact on the combustion process for biomass.



Figure 2. Combustion process from bamboo biomass to electricity [12]

1. **Pyrolysis**

The thermal ("pyro") decomposition ("lysis") of organic compounds occurs during pyrolysis at a moderate temperature (between 350 and 600 ºC) without oxygen. Charcoal (solid phase), condensable pyrolysis oils (heavy aromatic and hydrocarbons), and tars (liquid phase), as well as con-condensable gases or syngas (gaseous phase), are the byproducts of the pyrolysis process. The same manner that coal has been utilised, charcoal can also be used as a secondary fuel. Syngas, which is composed of carbon monoxide, hydrogen, and methane, can be burned in a boiler to produce electricity or in a petrol engine to provide power. Pyrolysis oils can be further processed in a "bio-refinery," which is quite similar to the present crude oil refinery process, to create biofuels and other useful chemical compounds. The operational parameters (temperature and residence time) determine the quantity of pyrolysis products. For instance, flash pyrolysis, which involves high temperature (500–600 ºC), short residence time, and high residence time, will maximise the production of condensable oils. On the other hand, a procedure known as carbonization that involves a low temperature (350–400 ºC) and a lengthy residence period will maximise the synthesis of charcoal and syngas.

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Figure 3. Pyrolysis reactions and end products [12]

1. ***Gasification***

The process of transforming a solid fuel into a gaseous fuel is called gasification. It is an intricate thermal and chemical conversion of organic material occurring at high temperatures with constrained airflow. A partial combustion stage is included in the gasification process along with the pyrolysis step. It occurs at extremely high temperatures with minimal oxygen, usually between 750°C and 1200°C. Syngas and ash are byproducts of the gasification process. The syngas is a mixture of combustible gases (carbon monoxide, hydrogen, and methane) and incombustible gases (carbon dioxide, nitrogen, and other gases). Approximately 40% of syngas' volume is made up of combustible gases that can be used to generate electricity or heat. Depending on the source of oxygen, syngas has a different heating value. The calorific value of the synthesised gas is low (4–7 MJ/m3) if air is used; however, if oxygen-enriched air is utilised, the heating value can approach 10-15 MJ/m3. Air is typically used in practise due to the cost-prohibitive nature of oxygen enrichment [12].When compared to combustion, gasification exhibits fewer thermal losses and improved fuel energy recovery. Under ideal circumstances, gasification has a potential 95% mass,dry efficiency for converting fuels. The efficiency is really lowered to 70–80% energy in the biomass recovered in generated gases as a result of heat losses and secondary reactions.

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Figure 4. Gasification process [12]

1. **Biochemical conversion**

Different strains of microorganisms are used in the biochemical conversion pathway to produce a range of biofuel products. The fundamental idea behind biochemical conversion is the fermentation of sugar or other materials found in biomass by microorganisms into fuels like ethanol and methane as well as other chemicals and heat. There are two primary techniques for bioconversion are:

* Anaerobic digestion is the biological breakdown of organic materials in biomass by anaerobic bacteria. Biogas (methane) (60 %) and CO2 (40 %) are the end products of this process [13].
* Fermentation: The process of fermentation is the breakdown of starch or sugar by bacteria and yeast to produce ethanol.
1. **Conclusion**

The utilization and trading of bamboo biomass fuels is restricted to a few producing nations, and it is still in its early stages on major markets for biofuel commodities. Utilization of bamboo by biomass producers and energy consumers will encourage the growth of supply chains, commerce, the responsible management of current bamboo resources, and the formation of new plantations. A thorough evaluation of the complete costs and advantages of bamboo biofuel production both technically and economically, as well as with regard to sustainability requires multidisciplinary research. Additionally, more research is required on bamboo biofuel value chains (biomass production, logistics plans, pre-treatment to enhance fuel properties, and conversion technologies), as well as on the potential for carbon sequestration, emissions from woody bamboo crop systems, and sustainability of related biofuel value chains. Finally, initiatives are needed to create bamboo carbon techniques and include them on the proper platforms.

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