

BAMBOO BIOMASS: SPRING OF GREEN ENERGY

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 converted using a number of techniques (thermal or biochemical conversion) to yield a variety of energy products (charcoal, syngas, and biofuels) that can be utilize to replace the current conventional energy products. This chapter mainly focus on potential of Bamboo biomass as spring 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

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I. INTRODUCTION

At the "Conference of the Parties COP26" in Glasgow in 2021, nations were urged to provide ambitious emission-reduction plans with 2030 reduction targets that would be consistent with achieving zero emissions by 2050. [1]. According to reports, during the summit, more than 90 countries committed to reducing greenhouse gas emissions and halting deforestation by 2030, and the world is now irreversibly moving towards 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 developing countries in coping with negative climatic impact, wealthier nations have pledged to double investment, or adaptation finance [2,3].

Bioenergy accounts for about 13% of the main energy supply and 70% of the global demand for renewable energy, which is mostly utilized to produce heat, power, and transportation fuel. Africa, Asia, the Americas, and Europe all have a biomass energy share of 96%, 65%, 59%, and 59% respectively. 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. This amount was made up of 7% liquid fuels, 86% main solid biofuels (such as wood chips, pellets, fuel wood, and charcoal), and 2-3% 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 around 23% of the world's primary energy supply [5]. Both now and in the future, there will be a greater need for alternate biomass supply chains and a greater role for international biomass commerce due to the rising global demand and bioenergy production goals. The use of bamboo as a bioenergy resource can aid in the implementation of modern biomass solutions for heating, electricity production, and transportation purposes as solid (such as chips, pellets, briquettes, and charcoal), liquid, and gaseous fuels.

Bamboo biomass energy has enormous potential as a conventional fuel energy substitute. Bamboo biomass can be converted by adopting various technique (thermal or biochemical conversion) to create a number of energy products (charcoal, syngas, and biofuels), which can be utilize to replace currently available conventional energy 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 construction material. Bamboo fibers are used to make board, paper, and textiles. 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 utilizing bamboo biomass as a spring to produce various forms of energy, including electricity and biofuels. In the Global South, bamboo is a plentiful resource. Millions of tonnes of bamboo resources are still not being fully used. It is also excellent to establish new plantations on the millions of hectares of degraded and potentially accessible land. About 50 Mt/year of bamboo might be produced and contribute to the diversification of the biomass feedstock portfolio if 10 percent of estimated present world bamboo resources could be efficiently exploited. Bamboo biofuels offer some countries that produce bamboo, like Colombia, Brazil, Indonesia, Nigeria, and South Africa, an opportunity to create new supply chains in support of the ongoing transition

from the trade of conventional fuels to that of biofuels. This is because these countries also export fuels, like coal and biofuels. [6]. In order to mitigate climate change and achieve the UN Sustainable Development Goals, sustainable bamboo production and utilization techniques can be used. [7].

II. PROPERTIES OF BAMBOO AS A SPRING OF BIOMASS

1. Morphophysiological Properties: Bamboo comes under the subfamily Bambusoideae of the family Poaceae, which includes 1250 species and is classified as a grass. Despite being grass family, they have a woody culm that can grow to a height of 15-20 metres or even 40 meters 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 15-25 °C and yearly precipitation of 900–1600 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.

2. Fuel Properties: Bamboo has a number of advantageous fuel characteristics, such as a low ash per cent 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). Bamboo also contains moisture, though much less than bagasse and maize stalk. It is similar to rice husk and rice straw in this regard. Because of the low moisture content, drying the biomass uses less energy, increasing utilization effectiveness. The table 1 below provides the fuel characteristic of several biomass feedstocks.

Table 1: Characteristics of Different Biomass [9]

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
Corn cob	40.11	0.95	45.55	13.68	11.198
Corn stalk	41.69	3.80	46.98	8.14	11.634
Bamboo (<i>Bambusadeecheyama</i>)	14.30	3.70	63.10	18.90	15.700
Bamboo (<i>Dendrocalamus asper</i>)	5.80	2.70	71.70	19.80	17.585

- 3. Yield and Productivity:** If bamboo is planted in an area with ideal conditions and is properly managed, it can produce the highest yield of around 50,000 kg/ha/annum [10].

III. BAMBOO BIOMASS ENERGY PRODUCTION TECHNIQUES

Energy can be extracted from bamboo biomass using a variety of conversion and processing techniques, 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 tearlier techniques. Microorganisms can convert biomass into biogas or biofuel through biochemical processes. Below is a schematic representation of the conversion of bioenergy.

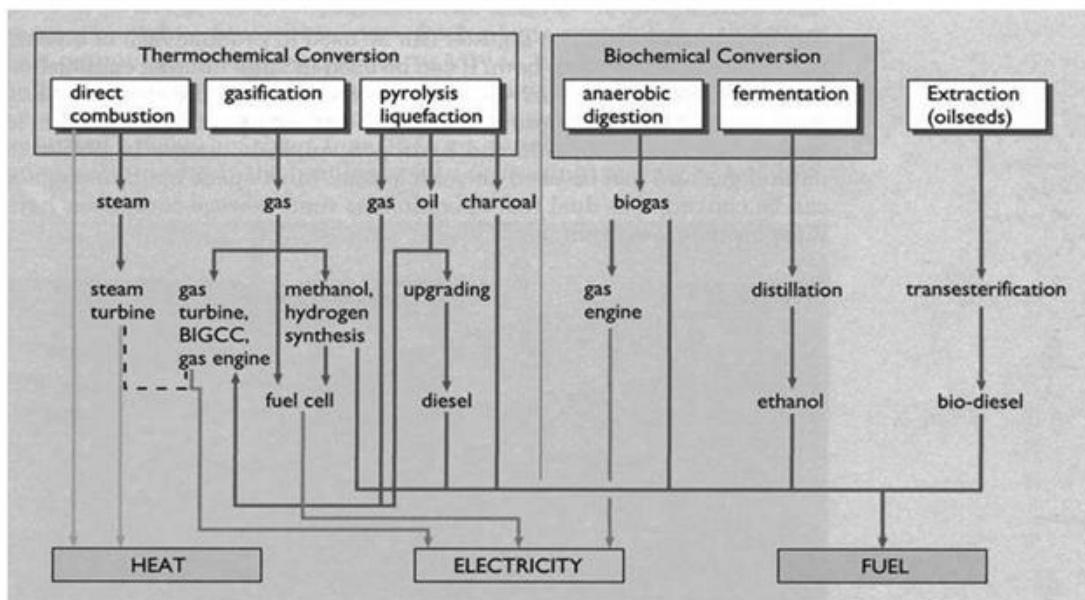


Figure 1: Main Bioenergy Conversion Routes [11]

- 1. Direct Combustion:** Bamboo dry biomass can be used as fuel to generate heat in households for cooking, heating, and water boiling. For people living in rural areas without access to electricity, it offers a dependable energy source. On a large scale, direct combustion of bamboo biomass is also employed in other industrial settings, such as co-generation to generate heat and power in thermal power plants that generate electricity, or in cement or steel mills. Through co-generation, it is feasible to decrease the extend of conventional fuel used in these facilities. The scientific principle of combustion process 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. The majority of combustion takes place inside of a chamber, after which heat is transferred from the hot gas stream to another fluid (usually water or air) via a heat exchanger. Then, using a turbine or engine, this fluid can be used to produce energy. Boilers are heat exchangers that use combustion to heat water. Water boilers are used to generate large amounts of steam at medium and high pressures (>20 bar) [12]. Combustion control is required to thoroughly burn the biomass in order to optimize

the amount of energy recovered, decrease the creation of tars, and release as little non-oxidized gases as possible, such as carbon monoxide (CO) and volatile organic compounds (VOC) [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.

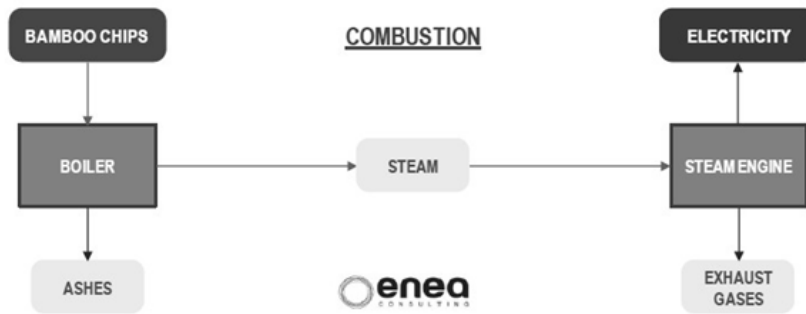


Figure 2: Process of Bamboo biomass combustion [12]

- 2. Pyrolysis:** Organic molecules undergo thermal decomposition ("pyro") and lysis ("lysis") during pyrolysis at a moderate temperature (between 350 and 600 °C) without oxygen. The by-products of the pyrolysis process include charcoal (solid phase), condensable pyrolysis oils (heavy aromatic and hydrocarbons), and tars (liquid phase), in addition to non-condensable gases or syngas (gaseous phase). Charcoal can be used as a secondary fuel in the same way as that of coal. Burning syngas, which is made up of carbon monoxide, hydrogen, and methane, in a boiler or a petrol engine can generate electricity or give power. In a "bio-refinery," which is relatively similar to the current crude oil refinery process, pyrolysis oils can be further processed to produce biofuels and other beneficial 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 °C), short residence time, and high residence time, will maximize the production of condensable oils. On the other hand, a procedure known as carbonization that involves a low temperature (350–400 °C) and a lengthy residence period will maximize the synthesis of charcoal and syngas.

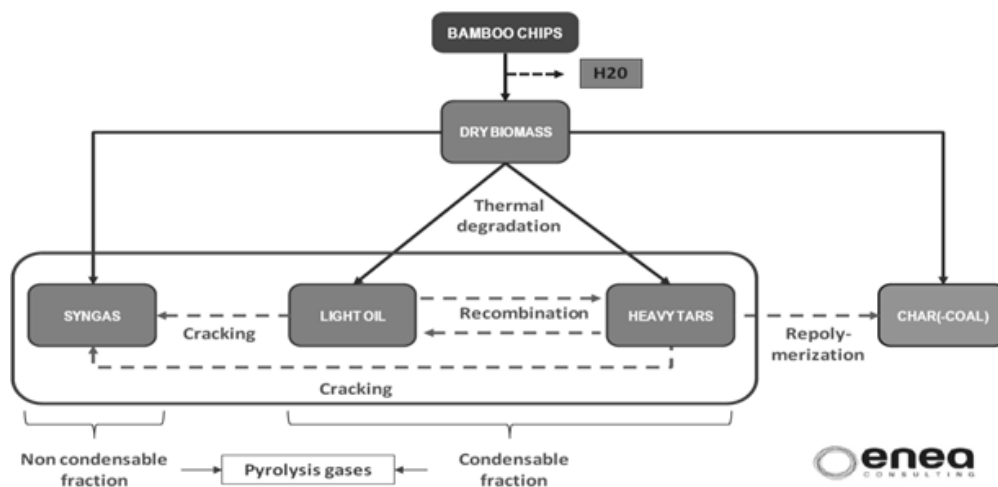


Figure 3: Pyrolysis reactions and end products [12]

3. 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. Combustible gases like carbon monoxide, hydrogen, and methane are mixed with incombustible ones like carbon dioxide, nitrogen, and other gases to create syngas. Combustible gases that can be burned to produce heat or power make up around 40% of the volume of syngas. The heating value of syngas varies depending on the oxygen supply. The calorific value of the synthesized gas is low (4–7 MJ/m³) if air is used; However, the heating value can reach 10-15 MJ/m³ if oxygen-enriched air is used. Air is typically used in practice due to the cost-prohibitive nature of oxygen enrichment [12]. In comparison to combustion, gasification displays lower thermal losses and better fuel energy recovery. Under ideal circumstances, gasification has a potential 95% mass, dry efficiency for converting fuels. Due to heat losses and subsequent processes, the efficiency of the biomass energy recovered in produced gases is really reduced to 70–80%.

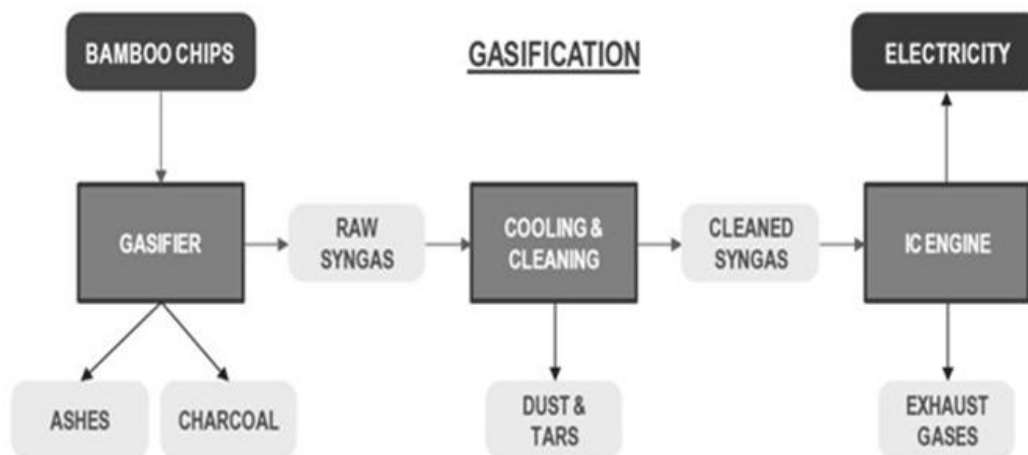


Figure 4: Gasification process [12]

4. Biochemical Conversion: A variety of biofuel products are produced using various strains of microbes in the biochemical conversion pathway. The basic concept behind biochemical conversion is the fermentation of sugar or other substances present in biomass by microbes into fuels like ethanol and methane as well as other compounds and heat. There are two primary techniques for bioconversion are:

- Anaerobic digestion is the biological degradation of organic molecules in biomass by anaerobic microorganisms. Biogas (methane) (60 %) and CO₂ (40 %) are the end products of this process [13].
- Fermentation: The production of ethanol by fermentation is the result of bacteria and yeast breaking down starch or sugar.

IV. 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. Utilizing bamboo will promote the development of supply networks, trade, prudent management of the existing bamboo resources, and the establishment and expanding 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. Further study is needed on the potential for carbon sequestration, emissions from woody bamboo crop systems, and sustainability of related biofuel value chains, in addition to biomass production, logistics strategies, pre-treatment to improve fuel properties, and conversion technologies. Finally, initiatives are needed to create bamboo carbon techniques and include them on the proper platforms.

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