

e-ISSN: 2584-2404

Volume 09 Issue 03 Sep-
Dec 2026

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Submission Date: Apr 08,
2026

Copyright Received Date:
Apr 16, 2026

Biomass Power Plants: Technologies, Performance and Environmental Impact

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ABSTRACT

Biomass is an increasingly important renewable energy resource, in part because it offers a way to utilize “waste” organic materials to produce electricity and heat using commercial and mature technology. Because of concerns with the depletion of fossil fuels and the adverse environmental impacts associated with their use, biomass is recognized to reduce greenhouse gases for sections of organic materials presently disposable in the environment. This study presents and reviews research regarding biomass power and cogeneration plants. Key considerations are a general description of a biomass power plant, key conversion technologies utilized in power generation, and details on plant performance and environmental effect.

This paper specifically focuses on various possible conversion processes: direct combustion for power generation; gasification, including plasma gasification, for electricity or heat generation; anaerobic digestion and bio-hydrogen production, with use as a fuel; and an overview of biorefining. The study looks at both urban and rural applications and notes the applicability of biomass for waste management. A detailed examination of greenhouse gas reduction for biomass is discussed, focusing on carbon neutrality. Implications related to emissions air, water, and land is outlined. Available information in the published literature regarding the performance and suitability of each method and future research directions were evaluated in order to gain further insights on the potential of using biomass as a future method for meeting our energy needs in a sustainable fashion.

Keywords:- *Biomass energy, biomass power plant, renewable energy, gasification, anaerobic digestion, environmental impact, power generation*

INTRODUCTION

The increasing demand for energy and the depleting reserves of fossil fuels are motivating industry, business and individual households to investigate the use of renewable energy sources. Fossil fuels – oil, gas and coal – have been the world's primary energy source for eighty years. Now they have thrust environmental issues like greenhouse gas emissions and global climate change to the forefront of public awareness. The tide of opinion is now strongly in favour of renewable energy as a clean and sustainable source of power.

One of the most promising of the many forms of renewable energy is biomass energy – organic material such as waste and byproduct materials are converted into energy. Biomass includes any material that is biodegradable, such as wood and wood waste, crops and crop waste, manure, municipal solid waste, and wastewater and sewage sludge. Of all the renewable resources, biomass has a particular advantage: it's not weather dependent, unlike solar and wind power.

Biomass power plants generate electricity from organic materials through thermal or chemical means. Electricity can be generated from biomass by several means including direct combustion to generate electricity at moderate efficiency levels and gasification to generate a syngas which can then be used to generate electricity at higher efficiency levels.

Another alternative includes anaerobic digestion to generate biogas which is used to generate electricity. All the different approaches have their own set of merits and demerits in terms of efficiency, cost

and the overall environmental impact in addition to considerations with respect to existing infrastructure.

Biomass energy is potentially carbon-neutral because the amount of carbon dioxide released during combustion is generally equal to the amount of carbon dioxide taken up by the plant during its growth. In addition, biomass can play a role in waste management by providing an alternative to landfilling of agricultural residues and other unmanaged organic waste that could otherwise negatively impact the environment. It can also generate additional income for farmers and rural populations by selling energy produced from crop residues left in the field after harvest.

Biomass energy has many benefits, however there are also many challenges involved with biomass energy production. The biggest challenge to biomass energy production is to find enough feedstock supplies. Next, the challenge of transporting and storing biomass is a huge issue in biomass energy production.

Another problem associated with biomass energy is that it has a lower energy density than oil and other fossil fuels. Furthermore, it is also important to ensure that emissions from biomass power plants are controlled efficiently. Mismanagement of biomass resources can lead to deforestation and environmental degradation. It is thus essential to evaluate and compare the options available with biomass power plant technologies to ensure that biomass is being utilized sustainably and efficiently. (When subject to heat-driven or living-cell methods, usable energy emerges from plant matter. One

method is better than another, depending not just on what kind of organic material is handy how wet it is, how much power you need and price considerations. In electricity-generating facilities, burning straight, turning into gas or breaking down without oxygen fall under common routes.)

Types of Biomass Conversion Technologies

From plant matter, usable energy emerges when treated with heat-driven or living-cell methods. Depending on what kind of organic material is available - along with how wet it is, how much power is needed, and cost factors - one method fits better than another. In facilities making electricity, burning straight, turning into gas, or breaking down without oxygen are common paths taken.

Burning stuff makes power - lots of places do it that way. Heat comes when plant material gets lit inside a chamber, turning water into vapor. That puffing gas pushes spinning parts tied to an energy machine. Works straight, hardly breaks, handles big jobs fine. Efficiency? Not super high. Smoke can escape unless things are watched close. Heat transforms plant material into burnable gas when oxygen levels stay low inside hot chambers.

This fuel mix - mostly made of carbon monoxide, hydrogen, because of heat-driven reactions - powers generators or spinning machines. Instead of burning raw biomass, turning it into gas first boosts performance while cutting pollution. Still, the gear needed runs intricate systems plus demands more money upfront than basic stoves. Breaking down organic material without oxygen, microbes create biogas through anaerobic digestion. Instead of burning pure coal, some plants mix in biological materials during combustion. Using both together cuts greenhouse pollution while keeping old

systems running much as they are. Though different in method, each path aims to make better use of renewable sources.

One tech might work well here but fall short there, so picking what fits means looking at how efficiently it runs, what it costs, and whether nature pays a price. Since materials differ in access and traits, matching method to need requires seeing how each performs under real conditions. What works today could change tomorrow when resource flow shifts or new demands appear.

LITERATURE REVIEW

Quite a number of review papers have been written regarding the feasibility of utilizing biomass energy as a sustainable resource for generating power. According to the authors of such papers, the use of biomass energy will ensure sustainable utilization of the residues obtained from agriculture as well as energy generation. Moreover, some review articles state that energy generated using biomass energy is quite stable, whereas energy generated using other sources such as solar and wind energies is not reliable.

As for previous researches, various types of biomass energy conversions have been considered. Two of them are biomass combustion and biomass gasification, the latter being applied most frequently. Biomass combustion technology has been selected due to its reliability and ability to operate in industrial scales.

However, as can be seen, it is rather inefficient compared to other types of biomass energy utilization. In addition, it negatively impacts the environment as much as others. However, biomass gasification appears to be the best solution due to producing syngas, which is high-efficient and eco-friendly. Another key aspect is the importance of anaerobic digestion as a route to energy production

from small scale or decentralized sources. Biomass available for anaerobic digestion is typically in the form of wet feedstocks such as agricultural wastes and dedicated municipal waste. Anaerobic digestion produces a suitable fuel, biogas, together with digestate suitable for fertilization. Although anaerobic digestion is less efficient as a route to energy production than many other thermochemical reactions it is a relevant process.

There are a number of studies on the co-firing of biomass with coal in existing power and combustion plants. It reduces greenhouse gas emissions and it is cheaper than building new biomass powered generation. There are also studies on pyrolysis and on biomass energy systems in general. Biomass offers environmental advantages of carbon neutrality and the ability to manage solid waste, while emissions and land use issues as well as biomass resource sustainability have been debated.

METHODOLOGY

The Research Methodology used for this research involves the evaluation of the technological components of biomass energy plants as well as their participation in sustainable energy production. Literature search for information regarding technological components of biomass energy plants will be conducted. The main objective of this research methodology involves studying biomass energy technology, its efficiency, and environmental impact.

Data Collection

Scientific literature will be the principal means of obtaining data for this research project, encompassing scientific reports, journals, and technical papers. Scientific literature relevant to this research topic has been obtained through keyword selection. Some of the keywords used for the selection of scientific literature include

“biomass power plant,” “biomass energy conversion,” “gasification,” “anaerobic digestion,” and “renewable energy systems.”

Process of Production of Biomass Energy

Biomass energy is a form of sustainable energy that includes the use of traditional biomass such as agriculture waste, wood waste and other organic waste biomass to generate electricity. Biomass energy production involves several steps starting with conversion of biomass to heat energy, heat energy to steam energy and steam energy to electricity by driving the turbines.

Energy conversion process can be represented as:

Biomass → Heat Energy → Steam → Turbine → Electricity

Biomass Conversion Technologies

For the biomass energy resource to be harnessed to provide power in the future, several technologies have been devised for the conversion of biomass to energy resources. This paper will focus on some three technologies for the conversion of biomass.

Direct Combustion

This is a widely employed means of power generation through the use of biomass. In this process biomass is burnt in a boiler to generate steam to turn a turbine. This method of power generation through the use of biomass is well established and easy to use.

Gasification

This involves the process where biomass is converted into synthetic gases (syngases) as a result of partial combustion. The syngases thus formed can be used to generate power through the use of gas turbines or internal combustion engines.

Anaerobic Digestion

This is the decomposition process of organic materials using microorganisms under anaerobic conditions. This process produces biogas which is capable of being used as a fuel to produce energy.

Combination with Other Renewable Energy Sources

It is feasible for biomass energy power plants to operate together with other renewable energy power plants such as solar and wind energy power plants. This helps in utilizing any additional renewable energy. The biomass energy is one of the most dependable sources of energy than other renewable energy sources.

Operational Problems

The methodological framework also considers the analysis of any problems associated with operating a biomass energy power plant. These include fuel supply, transport, storage, emission, and cost issues. Solutions to these problems are evaluated based on the literature review.

Evaluation Strategy

Data gathered from different research works have been analyzed and compared to find out suitable biomass technologies based on parameters like efficiency, cost, environmental effects, and applicability of the technology.

System Architecture of Biomass Power Plant

For understanding how the process of generating energy through biomass takes place, system architecture is considered. The system usually consists of stages involved in collecting the biomass, processing the fuel, converting biomass into energy through combustion or conversion process, producing steam, using a turbine generator to convert thermal energy into electricity, and producing power output.

The Process flow can be:

Biomass Collection → Processing → Combustion/Gasification → Steam Generation → Turbine → Generator → Electricity Output

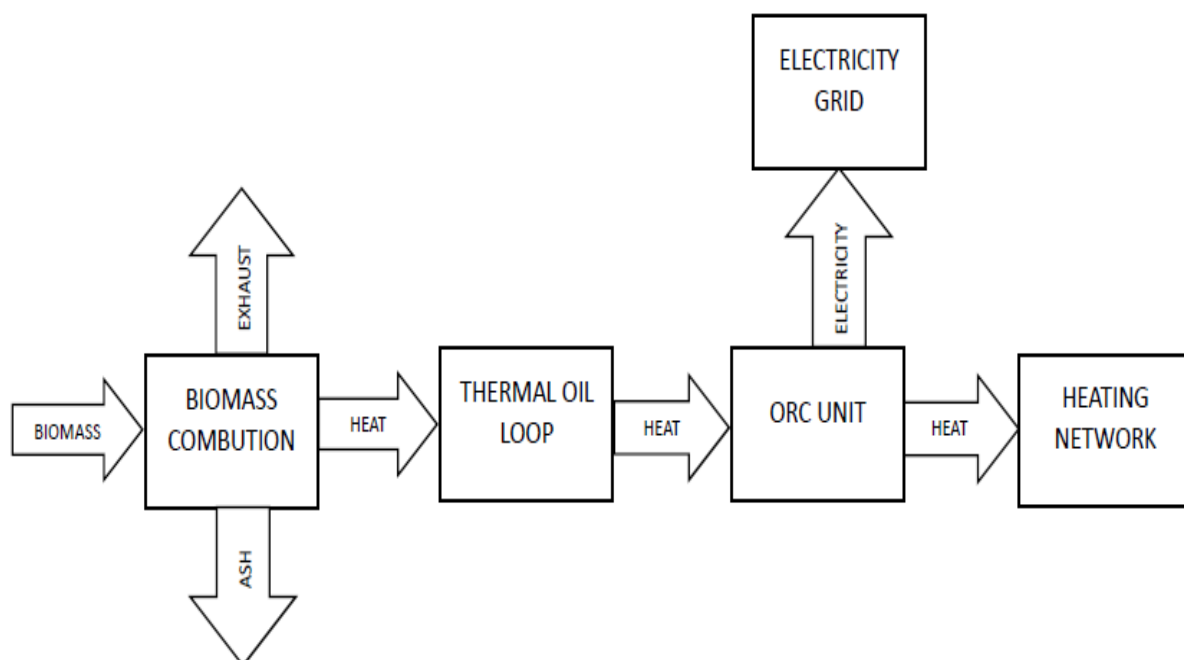


Fig.1:-Biomass Power Plant Working Using Organic Rankine Cycle (ORC)

Comparison of Biomass Energy Technologies

A comparison of different biomass power plant technologies has been performed on the basis of efficiency, advantages, and disadvantages of each technology.

Table 1:-Comparison of Biomass Conversion Technologies

Technology	Efficiency	Advantages	Limitations
Direct Combustion	Medium	Simple, low cost, Widely used	Lower efficiency, emissions
Gasification	High	Higher efficiency, Cleaner energy	Complex system, high cost
Anaerobic Digestion	Low - Medium	Suitable for wet Biomass, eco-friendly	Lower power output

Environmental and Economical Aspects

The approach involves analysis of environmental and economical aspects associated with biomass energy sources usage. Although the power plants based on the biomass are said to be environmentally friendly, inefficient burning results in emissions of greenhouse gases. As for the economical factor, while the cost of installation is relatively high, these power plants provide environmental benefits in the long run.

CONCLUSION

Biomass power generation is a developing renewable energy alternative that offers a range of benefits by converting organic waste materials into electricity. In this work, biomass power generation, its various conversion technologies (combustion, gasification and anaerobic digestion) and performance as well as environmental issues are reviewed.

Biomass energy has a number of benefits, including carbon-neutrality, waste management, and a reliable energy output compared to other intermittent renewable energy sources. Compared to incineration, gasification can achieve higher efficiency and cleaner energy, while currently the most common method of energy production from biomass is direct

combustion. Anaerobic digestion provides a method for utilizing “wet” biomass and organic waste for decentralized energy generation.

While there are not insurmountable challenges to developing a biomass power plant, there are several unique issues such as access to feedstock, feedstock logistics, feedstock energy density, and air and water emissions. While these are not easy to address, significantly better technology, more efficient use of resources and an informed approach to this area of energy production will help to maximize the benefits that can be obtained from this field.

Biomass power generation plants can become vital components in the overall development and expansion of sustainable energy sources. The rapid evolution of technology and large investment in biomass energy generation is likely to make it a significant contributor in pollution reduction and the shift to sustainable energy systems, mainly in regions that produce agricultural waste.

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