Green Waste Utilization for Sustainable Energy Engineering Application: A Path towards Green Circular Economy

Rohan Malka
Department of civil engineering
Amal Jyothi College of Engineering
Kottayam,Kerala,India
rohanmalka@gmail.com

Jerin Joseph Abraham
Department of Civil engineering
Amal Jyothi College of Engineering
Kottayam,Kerala,India
jerinjosephabraham1@gmail.com

Jobcy Johnson
Department of Civil Engineering
Amal Jyothi College of Engineering
Kottayam,Kerala,India
jjobcy1149@gmail.com

Sobin Saju
Department of Civil Engineering
Amal Jyothi College Of Engineering
Kottayam,Kerala,India
sobinkollamparambil2002@gmail.com

Febin Sam Philip
Department Of Civil Engineering
Amal Jyothi College Of Engineering
Kottayam,Kerala,India
febinsamphilip@amaljyothi.ac.in

Aju Mathew George
Department of Civil Engineering
Amal Jyothi College Of Engineering
Kottayam,Kerala,India
ajumathewgeorge@amaljyothi.ac.in

S.N.Kumar
Department of Electrical Engineering
Amal Jyothi College Of Engineering
Kottayam,Kerala,India
snkumar@amaljyothi.ac.in

Abstract—**This project work emphasis on the utilization of green waste for various energy engineering applications. The green waste is one of the major sources of waste in rural areas, where the agriculture is the livelihood of people. The conversion of green waste into activated carbon for the usage in batteries and super capacitors are gaining prominence and this project focuses on the hybrid combination of green waste sources for the generation of activated carbon. The utilization of green waste is vital since there are no chemical hazards in the materials and it serves as a waste disposal remedy also. This work focuses on the Kottayam district of Kerala, where pineapple, coconut husk and banana peels are available in a surplus manner. The green waste is processed for each type separately, since the activation agent composition and pyrolysis temperature differs for each raw material. After the generation of activated carbon separately from each source of green waste, mixing is carried out in various proportions. The activated carbon generated is utilized in the fabrication of electrodes and supercapacitors .**

Keywords—***Agro-waste, Pollution, Waste Management, Energy Application***

I. Introduction

In India, where a critical parcel of the population practices agriculture, faces a squeezing issue of overseeing the endless sum of agro wastes created every year, evaluated to be around 350 million tons agreeing to later thinks about. The plenitude of rural exercises in the nation requires quick and successful administration of these buildups to avoid natural corruption and contamination of soil, water. In reaction to this challenge, utilizing agro-waste for producing maintainable vitality assets rises as a practical arrangement. Feasible vitality sources, normally recharged and with negligible natural affect, are progressively in request in the midst of concerns over fossil fuel consumption and related natural results like climate alter and ozone layer consumption. By tapping into the potential of agro-waste as a renewable vitality source, India can address squander administration challenges whereas contributing to natural conservation and cultivating economic development[1]. This paper points to comprehensively investigate the utilization of agro-waste for vitality applications, highlighting its benefits, challenges, and innovative arrangements. It will dig into the range of agrarian buildups, their sources, and territorial wealth, evaluate the vitality potential of agro-waste, and look at different change advances such as combustion, gasification, pyrolysis, anaerobic absorption, and biochemical forms[2]. The paper will moreover illustrate the natural and financial preferences of leveraging agro-waste for vitality generation, nearby analyzing the approach and administrative system fundamental to advance its maintainable utilization. Also, case considers and victory stories will be displayed to exhibit best hones and lessons learned in saddling agro-waste for vitality generation. Through this investigation, the paper looks for to give experiences into the potential of agro-waste as a feasible vitality source and fortify advance inquire about and usage of agro-waste-to-energy activities, in this way contributing to a greener and more feasible future for India.

II. OVERVIEW OF AGGREGATE

Agro-waste, which is another name for agricultural waste, is the term used to describe the leftovers or byproducts that come from farming operations. After the main crop or product has been harvested, these materials are usually regarded as garbage. Various organic products, such as crop wastes, husks, shells, stems, leaves, and other plant parts not intended for direct human use, might be categorized as agro-waste. In an effort to turn these agricultural wastes into useful resources, agro-waste compounds have been investigated for their possible application in drilling muds as filter loss control agents. Typical instances of agrowaste, or agricultural wastes, are: husk from rice, cobs of corn, shells from coconuts, fibers from palm fruits, shells from palm kernel nuts, shells from groundnuts, husks from coconuts, straw wheat, straw barley. These agricultural leftovers are frequently plentiful and easily accessible as by-products of farming, which makes them suitable candidates for a number of uses, such as filter loss control agents in drilling muds[9].

Agro-waste management poses several challenges, including environmental pollution and economic inefficiencies:

A. Environmental pollution

Improper disposal of agro-waste can lead to environmental pollution. Burning agricultural residues in open fields can release harmful pollutants into the air, contributing to air pollution and respiratory issues. Dumping agro-waste in water bodies can contaminate water sources, affecting aquatic ecosystems and human health. Managing agro-waste in a way that minimizes environmental impact is crucial for sustainable agricultural practices.

B. Greenhouse gas emissions

Decomposing agro-waste in landfills or water bodies can produce Methane, a potent greenhouse gas that contributes to climate change. Methane emissions from organic waste decomposition can exacerbate global warming and have long-term environmental consequences. Implementing proper waste management strategies, such as composting or anaerobic digestion, can help reduce greenhouse gas emissions from agro-waste.

C. Soil degradation

Leaving agro-waste in the fields or disposing of it improperly can lead to soil degradation. Accumulation of agricultural residues can alter soil structure, reduce soil fertility, and increase the risk of erosion. Managing agro-waste through sustainable practices like mulching or incorporating it back into the soil as organic matter can help improve soil health and productivity.

D. Pest and disease management

Improper handling of agro-waste can attract pests and pathogens, posing risks to crop health and agricultural productivity. Residues left in fields or storage areas can provide breeding grounds for pests and disease vectors, leading to infestations and crop damage. Implementing effective pest and disease management practices, such as timely removal or treatment of agro-waste, is essential to prevent agricultural losses.

E. Economic inefficiencies

Inefficient agro-waste management practices can result in economic losses for farmers and agricultural industries. Failure to utilize agricultural residues effectively can waste valuable resources that could otherwise be used for energy production, soil enrichment, or other beneficial applications. Developing cost-effective and sustainable agro-waste management strategies can help maximize the economic value of agricultural residues while minimizing waste.

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Addressing these challenges requires a holistic approach that integrates environmental considerations, economic incentives, and stakeholder engagement. Implementing sustainable agro-waste management practices, such as recycling, composting, and bioenergy production, can help mitigate environmental pollution, reduce economic inefficiencies, and promote resource conservation in the agricultural sector[9].

III. UTILIZATION TECHNOLOGIES

Agro-waste, also referred to as agricultural waste, constitutes residues or by-products arising from agricultural activities, typically left over after the primary crop has been harvested or processed. The conversion of this waste into energy holds significant promise for addressing both environmental and energy sustainability challenges. Several technologies have emerged to facilitate this conversion, each with its own set of principles, advantages, and limitations[8].

A. Biomass Combustion

One prominent method involves biomass combustion, where agricultural residues are burned in the presence of oxygen to produce heat energy. This energy can be utilized for various purposes, including heating, electricity generation, or industrial processes. Biomass combustion boasts relatively simple technology, widespread availability, and suitability for decentralized energy production. However, it is not without its drawbacks, as it often leads to the emission of pollutants such as particulate matter, ash, and greenhouse gases. Additionally, some instances may involve inefficient utilization of energy.

B. Anaerobic Digestion

Another approach, anaerobic digestion, relies on biological processes where microorganisms break down organic matter in the absence of oxygen, yielding biogas (methane and carbon dioxide) and digestate. This method offers advantages such as the production of renewable biogas for energy, reduction of organic waste volume, and the generation of nutrient-rich digestate suitable for use as fertilizer. However, optimal performance requires specific conditions regarding temperature and pH, and the process typically involves longer processing times compared to alternative technologies

C. Pyrolysis

Pyrolysis presents a different avenue, involving the heating of agricultural residues in the absence of oxygen to decompose the organic matter into biochar, bio-oil, and syngas. This method offers multiple benefits, including the production of biochar for soil amendment, bio-oil for energy, and syngas for heat and power generation, with the potential for carbon sequestration. Nevertheless, pyrolysis is characterized by high initial investment costs, a complex process requiring meticulous control of temperature and residence time, and the potential for emissions of volatile organic compounds.

D. Gasifiction

Gasification represents another technological option, converting agricultural residues into a combustible gas (syngas) through a reaction with a controlled amount of oxygen and steam at high temperatures. This process enables the production of syngas for electricity generation, heat production, or biofuels, offering higher energy efficiency compared to combustion. However, gasification is complex, sensitive to feedstock composition and moisture content, and may entail challenges such as tar formation and equipment corrosion.

E. Biochemical Processes

Lastly, biochemical processes involve the use of enzymes or microorganisms to convert agricultural residues into biofuels such as ethanol or biodiesel. This approach presents advantages such as the production of liquid biofuels suitable for transportation and the potential for higher energy density compared to solid biomass. Nevertheless, it requires specific enzymes or microorganisms for efficient conversion, may face competition with food production for feedstock, and could entail high water usage in certain processes.

Each of these technologies offers unique opportunities and challenges in converting agro-waste into energy. The choice of technology depends on various factors, including feedstock availability, energy requirements, environmental considerations, and economic feasibility. An integrated approach that combines multiple technologies in a cascading manner holds the potential to enhance overall efficiency and sustainability in agro-waste utilization for energy production. By exploring and implementing these innovative solutions, societies can move closer to achieving a greener and more sustainable future.

IV. CHALLENGES AND BARRIERS

Logistical constraints present a primary challenge in the widespread adoption of agro-waste for energy applications, encompassing the collection, transportation, and processing of diverse agro-waste types. The decentralized nature of agrowaste sources, coupled with varying quantities throughout the year, complicates efficient utilization efforts. Policy and regulatory issues further impede adoption, with inconsistent regulations, insufficient support, and unclear guidelines surrounding agro-waste conversion into energy[7]. This uncertainty regarding incentives, subsidies, and compliance requirements discourages investment in agro-waste utilization projects, hindering progress in this area[8].

V. POTENTIAL SOLUTIONS AND STRATEGIES

Implementing an integrated supply chain management system is crucial for optimizing the utilization of agro-waste for energy generation. By streamlining the collection, transportation, and processing of agro-waste, logistical constraints can be effectively overcome. Collaboration with local farmers, waste management agencies, and energy producers enables the optimization of agrowaste flow, ensuring a reliable and efficient supply for energy generation purposes. Engaging with policymakers, regulatory bodies, and stakeholders is essential to address the barriers related to policy uncertainty hindering agro-waste utilization projects. Advocating for supportive policies, clear guidelines, and incentives can create a conducive environment for investment and implementation. By encouraging the development of frameworks for agro-waste utilization, stakeholders can foster innovation and enhance the attractiveness of agro-waste as a renewable energy source. Investing in research and development of advanced technologies is critical for improving the efficiency and scalability of agro-waste utilization for energy generation. Technologies such as bioenergy, biogas, and biofuels offer promising opportunities for converting agro-waste into valuable energy products. Innovations in biomass conversion technologies and energy storage systems can further enhance the overall effectiveness of agrowaste-based energy generation, making it a more viable and sustainable solution for meeting energy needs[6].

VI. .FUTURE PROSPECTS AND TRENDS

The circular economy approach, advocating for the reuse, recycling, and re purposing of resources, is gaining momentum in agro-waste utilization for energy generation, promising sustainable resource management, reduced waste generation, and heightened energy security. Meanwhile, ongoing advancements in bioenergy technologies, encompassing anaerobic digestion, pyrolysis, and gasification, hold substantial potential for efficiently converting agro-waste into renewable energy sources[8]. Integration of these bioenergy systems with existing infrastructure and grid networks stands to further propel the adoption of agro-waste for energy applications. Furthermore, collaborative endeavours spanning agriculture, energy, and waste management sectors can foster synergies in agro-waste utilization, facilitated by public-private partnerships, knowledge exchange platforms, and cross-sectoral initiatives, thereby accelerating the transition toward a more sustainable and resilient energy system centered around agrowaste resources.

The project proposal underscores the significance of harnessing agro-waste as a renewable energy resource to tackle environmental challenges and promote sustainable practices.

VII. CONCLUSION

Agro-waste, originating from diverse agricultural activities, presents vast potential for applications such as composting, pyrolysis, and energy production, highlighting its importance as a valuable resource rather than a burden on the environment. Through conversion processes yielding valuable resources like activated carbon, electrodes, and composite materials, agro-waste not only minimizes waste but also offers avenues for renewable energy generation, underscoring its dual benefits in pollution mitigation and energy production. The project addresses the environmental impact of inadequately managed agro-waste, emphasizing the need for efficient utilization in energy engineering applications to mitigate pollution and establish a sustainable circular green economy. Recommendations for future research include scaling up green waste management plants in rural areas, exploring hybrid combinations of agro-waste for enhanced efficiency, and investing in technological advancements. These proposals highlight the importance of interdisciplinary collaboration, innovation, and investment in addressing agro-waste challenges and advancing towards a greener economy. In conclusion, by focusing on efficient agro-waste utilization for renewable energy and sustainable practices, future research endeavors have the potential to significantly contribute to environmental conservation and resource efficiency, aligning with the transition towards a more sustainable future.

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