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CONFERENCE PAPER

TECHNO-ECONOMIC ASSESSMENT OF BIOMASS ENERGY POTENTIAL IN INDIA

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Abstract

Energy demand is steadily rising due to the continuous expansion of the global economy. Consequently, power generation planners, policymakers, and governments must give significant attention to the growing challenge of energy consumption. While fossil fuel reserves are finite, renewable energy resources are abundantly available in nature. Therefore, promoting renewable energy is essential for safeguarding both the environment and human health. This study addresses various issues related to biomass potential and biomass based power generation As bioenergy represents a major component of renewable energy, multiple factors have been considered in reviewing the existing literature on biomass power generation. The research focuses on the present status of biomass energy in India. Biomass energy is cost-effective and environmentally friendly, and it also contributes to reducing environmental pollution. It holds considerable promise as a sustainable energy solution, particularly for rural areas in India. Additionally,biomass energy generation offers significant opportunities for innovation and practical applications in remote regions. To fully harness India's future energy potential, it is essential to develop efficient systems and utilize sustainable, renewable, and non-conventional energy resources. Biomass can also be used to produce ethanol, which is considered one of the most valuable renewable energy sources worldwide.

Introduction:-

India, home to about 17.5% of the world's population, ranks as the second most populous nation globally (Maurya et al., 2015). It is also one of the fastest-growing major economies, placing a substantial and steadily increasing demand on its energy resources. To address this rising demand, the Indian government is actively promoting electricity generation from renewable sources such as solar, wind, and biomass, which are either freely available or relatively low-cost. These renewable resources play a crucial role in enhancing national energy security.

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India is currently the fourth-largest consumer of LPG worldwide, following the United States, China, and Japan, and ranks third in household LPG consumption after China and the United States (Chandra et al., 2010). With such a rapidly growing energy demand, it is essential for the country to develop efficient systems that can harness biomass energy in alignment with its future requirements. Biomass originates from green plants that convert solar energy into organic matter through photosynthesis and includes both terrestrial and aquatic sources. It consists of organic materials where solar energy is stored in the form of chemical bonds. This stored energy is released when the bonds between carbon, hydrogen, and oxygen atoms are broken through processes such as combustion, digestion, or decomposition. Biomass has historically been a vital energy source and continues to contribute significantly, accounting for approximately 10–14% of India's total energy consumption (McKendry, 2002; Yuanchun, 2013).

India's annual biomass availability is estimated to exceed 500 million metric tonnes. Of this, about 120–150 million metric tonnes are considered surplus, corresponding to a power generation potential of nearly 18,000 MW, as reported by the Ministry. The country generates approximately 450–500 million tonnes of biomass each year, with biomass contributing around 32% to the total primary energy mix. The current installed capacity for biomass-based power generation is estimated at over 18,000 MW, while the overall potential is believed to reach up to 50,000 MW. Despite this significant potential, the contribution of biofuels to the total fuel mix remains limited. Ethanol blending in petrol is currently around 5%, mandated in select states, while biodiesel has yet to achieve commercial availability. However, the government has set ambitious targets to increase biofuel utilization, including meeting up to 20% of diesel demand through biodiesel in the future.

Materials and Methods:-

Biomass and Its Sources:-

Biomass energy refers to renewable organic materials that can be utilized for energy production. These resources include agricultural residues, wood and wood-based wastes, animal waste, aquatic vegetation, municipal solid waste, and other organic matter. Biomass has been used as a fuel since ancient times and is widely available across the globe. Although it is often present in large quantities, its economic potential has not been fully realized due to inefficient utilization. Biomass offers several environmental and socio-economic benefits, including carbon neutrality, lower emissions of pollutants such as SOx and NOx, enhancement of soil and water quality, support for biodiversity, improvement of landscapes, employment generation, and rural development. There is growing emphasis on developing advanced technologies to improve the efficient utilization of biomass resources. One of the key advantages of biomass is its versatility, as it can be converted into solid, liquid, or gaseous fuels through various conversion processes, making it suitable for diverse applications. Given its technical feasibility and economic potential, biomass is expected to play a significant role in future sustainable energy systems.

In an agriculture-based country like India, biomass energy potential is particularly high. With an estimated annual biomass availability of about 500 million tonnes, the power generation potential is around 17,000 MW. However, the currently installed capacity using biomass conversion technologies is approximately 500 MW. Biomass can be converted into usable energy through different methods, broadly categorized into thermochemical and biochemical processes. Biochemical conversion relies on microorganisms for energy generation, whereas thermochemical processes involve the application of heat. Biodiesel production can be achieved from plant sources such as jatropha, curcas, neem, mahua, taad, barley, and other wild species. India has about 63 million hectares of wasteland, out of which nearly 40 million hectares are suitable for cultivating jatropha and curcas. The government had earlier proposed plantation of jatropha over 11.2 million hectares by 2012. To promote biomass energy, the Ministry of New and Renewable Energy (MNRE) provides Central Financial Assistance (CFA) in the form of subsidies and incentives, particularly for projects demonstrating higher efficiency and energy output (Seth et al., 2015). Bioenergy production processes are generally classified into dry and wet methods. Dry processes include combustion and pyrolysis, while wet processes involve anaerobic digestion, fermentation, and gasification.

Combustion:-

Biomass combustion involves burning organic materials to release energy. This is one of the oldest and simplest technologies used by humans, initially for heating and later for generating power through steam. While wood remains the most common fuel, a wide range of materials can be effectively burned, including sawmill residues, agricultural byproducts such as straw, bark, sawdust, and
shavings, as well as dedicated energy crops like

switchgrass, poplar, and willow. In addition, pelletized forms of agricultural and wood waste are increasingly used due to their convenience in handling. Combustion is a well-established and efficient method for extracting energy from biomass. It is economically viable and widely implemented on a commercial scale. However, in many traditional systems, a significant portion of heat energy is lost and not effectively utilized. In developing regions, improved stove designs made from materials like mud and scrap iron can enhance efficiency and reduce energy wastage (Seth et al., 2015).

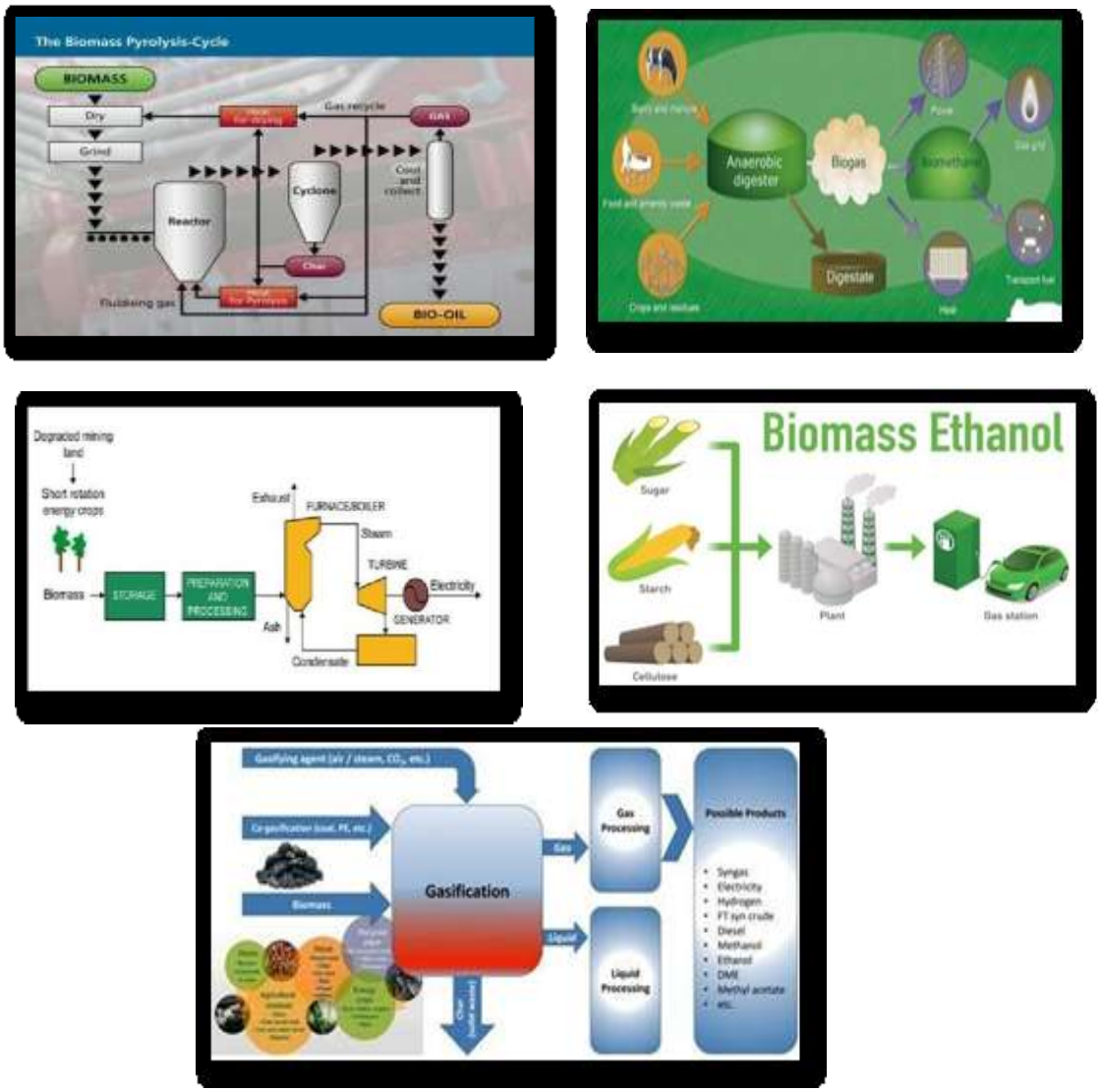

Fig.1 Different biomass processe

Pyrolysis:-

The heat degradation of biomass in the absence of oxygen is known as pyrolysis. It is the fundamental chemical reaction that occurs naturally in the first two seconds and is the precursor to both combustion and gasification. Biochar, bio-oil, and gases such as methane, hydrogen, carbon monoxide, and carbon dioxide are among the byproducts of biomass pyrolysis.

Anaerobic Digestion:-

Wet sewage, sludge, animal dunk, or green plants are allowed to degrade in a sealed tank to produce biogas in the absence of oxygen. Wood chips, straw, hay, and husk can be used as well, although digestion takes significantly

longer. 450-500 litres of biogas can be expected from 1 kilogramme of organic material. After decomposition, the residue is a good fertiliser or manure

Fermentation:-
The fermentation of sugar solution and natural yeast produces ethyl alcohol. Crushed sugar beet and fruit are examples of feedstock. Sugar can be made from cellulose and vegetable starches through pulping or boiling, or from cellulose through acid treatment. After 30 hours of fermentation, the solution contains 6-10% alcohol, which can be separated via distillation and used as a fuel. After the sugar has been fermented, yeast can be added to it. As a result, the fermentation process creates alcohol, which has large energy reserves and may be utilised as a vehicle fuel. After the sugar has been fermented, yeast can be added to it. As a result, the fermentation process creates alcohol, which has large energy reserves and may be utilised as a vehicle fuel.

Gasification:
Biomass gasification is the incomplete combustion of biomass that produces combustible gases such as carbon monoxide (CO), hydrogen (H_2), and methane traces (CH_4). Producer gas is the name given to this mixture. Producer gas can be used to fuel internal combustion engines (both compression and spark ignition), can be used to replace furnace oil in direct heat applications, and can be used to produce methanol – an extremely appealing chemical that can be used as a fuel for heat engines as well as a chemical feedstock for industries – in an economically viable manner (Rajvanshi, 1986).

Results and Discussions:-

Power Generation from Renewable Sources: Indian Scenario:-
Total gross power capacity will increase from 284 GW in 2015 to 670 GW in 2030, with annual electric power production more than tripling from 1100 TWh to 3450 TWh. However, the predicted increase in renewable energy capacity is modest. India had targeted 175 GW of alternative energy by 2022, but advances have been uncertain since then (IRENA, 2017)

Biomass potential/resources:-
Kumar et al. (2015) conducted a study on the potential of biomass as a source of energy. In India, there is a lot of biomass that can be used to generate electricity. Many biomass-based power projects are operating in the country and doing successfully, particularly in rural areas. According to Singh et al., (2008), the state has a large amount of agricultural biomass that can be utilised for electricity generation. Biomass availability is spatial in nature. The costs of collecting and transportation have been calculated using various vehicle carrying capacities. According to McKendry (2002), the environmental impact of burning crop leftovers can be reduced by properly replanting biomass. All biomass can be used to generate steam, which can then be used in turbo-generators to generate electricity. Biomass from agricultural leftovers of various crops is accessible in several states of the country, according to Hiloidhari and Baruah (2014). The study computed an expected amount of biomass; various crops such as rice, wheat, and cotton are classified as the main sources of agricultural residue in India.

Biomass based power generation:-
Even if there are abundant agricultural leftovers in many agricultural-based states across the country, according to Singh et al., (2011), power production projects must be thoroughly studied. GIS was utilised in this work to plan a biomass power plant in the research area. There has been optimization of power plants as well as collection centres. The goal of this research is to reduce the different expenses involved with crop residue management for power plants and collection centres. The goal of this research is to reduce the different expenses involved with crop residue management in power plants. This study proposes a cost-effective power generating strategy based on the number and size of power plants. For a set amount of electric power generation (20 MW), this article provides possible combinations of varied capacity of power plants and collection centres. According to Singh et al., (2020), the total generation of electricity from biomass in the district of Bhatinda is 367.69 MW/year which is a considerable amount of electricity to serve the consumers. Two to four biomass-based power plants have been proposed by the authors at their optimal locations. This study employs the Ant lion optimizer. Paddy and wheat are the most important crops, accounting for 96 percent of total biomass produced in Bathinda district. According to the proposed research, generating electricity from agricultural waste is a better choice than burning it in open fields. This will not only help to reduce air pollution, but it will also help farmers increase their revenue. It will also ensure future generations' energy security.

Barriers in biomass power generation:-

According to Jain (2016), relatively little effort has been done in Rajasthan on biomass power generation. The author of this study attempted to discover the issues that power generators encounter. This document also discusses the future scope and tactics for the organizations' success. Various factors such as biomass product quality, handling of large materials, weather- related variability, localised agricultural capacity, seasonality, and demand can be addressed by implementing new technologies, and the government can take steps to assist power utilities and new entrepreneurs with financial and social assistance. Singh (2016) focuses on providing facilities to farmers for the delivery of biomass and to plant owners for the efficient utilisation of biomass. According to the author, one-third of total biomass is available for power generation, which can be expanded by enacting appropriate legislation. The author has also seen how local entrepreneurs might be motivated to supply biomass to the plants. The author proposes a decentralized system of collecting centers, with each collecting centre covering 2-3 communities nearby. In the event of crop failure, power plant operators are also required to employ energy crops as a substitute for crop waste. According to the text, the government should also provide appropriate infrastructure and financial rewards to society as a whole.

Renewable Energy Education in India:-

After that, India is a developing country that meets its energy needs through export (conventional energy resources). India's national government is now focusing on generating energy from renewable sources. These were included in their five-year strategy. India's technical institutes provide one or two semester courses on renewable energy. In India, some technical institutes have begun to offer undergraduate and postgraduate programmes in renewable energy. The government is also financing student projects that use sustainable energy sources (Khare et al., 2015).

Conclusion:-

India possesses substantial biomass resources, estimated at nearly 500 million metric tonnes annually, of which about 120–150 million metric tonnes are currently used for energy generation. The government has set an ambitious target of producing up to 50,000 MW of electricity from biomass. During the 2013–14 financial year, LPG production stood at 13,123.29 TMT, while demand reached approximately 16,824.72 TMT, indicating a significant supply gap. Bioethanol derived from biomass fermentation represents a considerable energy resource and can be used as an alternative automotive fuel, as successfully demonstrated in countries like Brazil. The Indian government has also planned to expand biodiesel production to meet nearly 20% of the nation's diesel demand by 2021. Advancing and modernizing biomass energy systems in India can provide notable socio-economic benefits for both rural and urban communities. When efficiently developed and implemented, biomass energy systems can serve as environmentally sustainable energy solutions that support long-term development goals. However, to make a meaningful contribution to current energy demands, biomass production must be scaled up significantly. Biomass is not only cost-effective but also environmentally friendly, offering a sustainable alternative to conventional energy sources while maintaining efficient production practices. Future projections indicate a substantial rise in biomass energy demand up to 2025. This growth is expected to be driven by increasing population, expanding industrial activities, and technological advancements that enhance biomass fuel quality and improve its conversion into efficient energy carriers.

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