Biomass-Based Microgrid: A Case Study on its Aspects in the State of Punjab in India

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Abstract. The microgrid is an emerging power system. It works on the interconnection of renewable energy resources (RES) such as solar, wind and biomass, which is a promising field for researchers to explore the scope of power production from unconventional energy resources. Various combinations of RES like solar, wind, biomass and small-hydro power plants are available at different geographical locations. As a result, the combined use of various RES is drawing more attention and is frequently employed as an alternative to energy based on fossil fuels. Economic facets of these systems are suitably promising to consider them for raising the growth of power generation capability in developing countries. Objective of this paper is to present a detailed study of the biomass-based hybrid renewable energy systems (HRES) in terms of their cost of energy and carbon emission. Moreover, the deployment of biomass-based power generation technology in Indian and international energy scenarios has been discussed showing the availability along with the availability of RES in Punjab, India. From the literature review it reveals that a viable configuration of microgrid which can generate power by direct combustion and gasification of biomass should be proposed and optimized to ensure more reliability and less carbon footprints in power generation.

1 Introduction

The practice of renewable energy for power production techniques are to be executed having less carbon footprints [1]. With the help of a microgrid the power generation can make use of energy resources including sun, wind, biomass, biofuels, hydropower, and geothermal, among others. Implementation of microgrid helps in the reduction of congestion cost, line losses and line costs whereas energy efficiency increases [2]. The location's geographic characteristics, such as the climate, topology, and fuel supply, will influence the distributed energy resource (DER) options for the microgrid [3]. In terms of price, dependability, and efficiency, a hybrid system based on renewable energy presents a superior alternative than a system based solely on fossil fuels. The most potential power generating sources are solar and wind. However, these sources rely on uncertain climatic conditions [4]. Biomass can be employed in the hybrid system as a variable, controllable energy source that can be supplied when the supply of wind and solar energy is insufficient. Other sources, such fuel cells and biomass, can be added to a PV wind hybrid system to increase its reliability [5]. The use of

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bioenergy can lead to the reduction in net CO\textsubscript{2} emission as compared to fossil fuels [6]. Its utilization for energy generation can play an important role for expansion of power sector of the country [7]. That further can reduce the open burning emission and can be a source of income for the farmers. So it’s necessary to estimate the availability of biomass and explore the different types of technologies available in the country. This study attempts to provide a comprehensive survey in this field.

# 2 Biomass classification and its applications

Biomass can be classified as follows [4]:
- Silviculture crops made from agricultural and forestry waste.
- Herbaceous plants: Napier grass and weeds.
- Sea grass beds, kelp, coral reef, aquatic weeds, plants, water hyacinth, etc.
- Wastes include industrial trash, animal waste, urban waste, and sewage sludge.

## 2.1 Biomass conversion technologies

Biochemical and thermochemical conversion are the two main techniques used to extract bioenergy from biomass. In comparison to biochemical processes, thermochemical reactions are more efficient [5]. Direct combustion, pyrolysis, gasification, and liquefaction are the main thermo-chemical conversion processes whereas; bio-chemical conversion includes anaerobic digestion, mechanical extraction as shown in Fig. 1.

![Biomass Conversion Technologies](image)

**Fig. 1.** Biomass conversion technologies

### 2.1.1 Biomass Combustion

This technology is to convert biomass to heat [5], that can be reused as electricity [6]. The biomass with less water content is preferred [7].
2.1.2 Biomass Gasification

The biomass is converted to gases that can be used as fuel in gas engines and gas turbines [8].

2.1.3 Pyrolysis

A conversion of biomass into bio-oil with good power. Although bio-oil can be utilized in engines, there are still certain challenges to be solved, such as its corrosivity and low thermal stability [6].

2.1.4 Liquefaction

In this hydrogen is used to catalytically break down biomass into pieces of light molecules. These light pieces also underwent re-polymerization to form heavy, greasy molecules [7] [8]. Currently, the expense of the complicated reactor and feeding system makes its economic viability dubious [11] [9].

2.1.5 Fermentation

Commercially, fermentation is utilized to turn starch and sugar crops into ethanol. The starch in the biomass is broken down into sugar by enzymes, and yeast then turns the sugar into ethanol. 1000 kg of dry maize can be used to make 450 liters of ethanol. The conversion of biomass is complicated because long-chain polysaccharide molecules are present [7].

2.2 Energy conversions

2.2.1 Biomass Anaerobic digestion

The transformation of organic material into a gas is anaerobic digestion. To produce biogas with efficiency of 21% [13].

2.2.2 Mechanical extraction

The majority of the systems incorporating solar, wind, diesel, biomass, and energy storage systems are the focus of this study [10]. In the past ten years, the use of solar and wind energy systems to generate electricity has increased across the globe due to their extensive use in nature, cleanliness, low maintenance requirements [11].

3 Cost of energy

As per [12] the use of biomass in hybrid systems is economically feasible. A biomass-fueled generator and gasifier are part of a hybrid renewable energy system (HRES) that is being developed by [13]. Reductions are made to the system's overall levelized cost of energy (LCOE). In an Indian setting, a network of power delivery systems that includes solar modules (SPS), wind turbines (WT), biomass gasifiers together with battery is given an economic evaluation [14]. Aaalysis reports a reduction of 5.6% in cost using combination of PV and gasifier. When compared to a solar module-fuel cell system with the same load demand, employing a solar module-biomass gasifier unit results in an annual cost savings of 8.1% [15]. Due to reduced investment costs and generation costs, stand-alone biomass
powered systems are preferred over stand-alone solar powered systems in a cost optimization analysis utilizing HOMER [16]. Two approaches to microgrid operation optimization were put forth in [21]. The operational cost of the microgrid was greatly decreased when fuzzy expert system (FES) was utilized. For the microgrid that was operating in island mode and was linked to the grid, the suggested technique saved 3.34% and 1.43%, respectively, using FES. Salix in China has been evaluated economically and environmentally [22]. A hybrid energy system is being studied in Kerala (India) to meet the primary load demand of 56 kWh/d and the deferrable load demand of 17 kWh/d (scaled annual average). According to the HOMER modelling results, the cost of energy is determined to be less than a pico-hydel/diesel system. Additionally, a biomass gasifier hybrid energy system is recommended for use in India's rural areas near the Western Ghats [17].

Wind and biogas energy systems are found not feasible in a case study from Canada [18]. In a semi-arid part of Brazil, hybrid CSP-biomass plants are being researched to provide electricity more cheaply [19][20]. There has been a proposal for a biomass integrated that incorporates both direct and indirect gasification processes [21]. Solar–Biomass Generation Plant [22] proposes a food waste biogas plant and grid-connected rooftop PV with mechanical solar tracking technology. In terms of power generation, complexity, and fuel cost, a PV module with a biogas generator has been shown to be the most suitable [23]. The article discusses how rice husk in Cambodia could be used to power rural areas [24]. The rural population of Cambodia can benefit from access to electricity in a sustainable way thanks to rice husk. A financially sound business plan is also offered for supplying grid-quality electricity to rural residents without the need for grants or subsidies.

4 Carbon emission

In order to reach the potential for 100% electric energy in Awaji Island, Japan, renewable energy sources such biomass, wind power, and PV are being researched [30]. Compared to emission levels in 2010, the 2050 scenario might lower CO₂ emissions by more than 60%. [31] discussed the operational experience of a 100 kWe gasification power station that was wired into the grid in Karnamata [25]. By implementing biochar as a carbon storage mechanism greenhouse can be reduced [26]. Utilizing life-cycle assessment (LCA), it was determined what effects future power sector with more percentages of wind and biomass energy would have on the environment [27].

5 Optimization Technologies

Optimization techniques used are presented in Table 1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Technique Used For Optimization</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Genetic Algorithm</td>
<td>[28]</td>
</tr>
<tr>
<td>2</td>
<td>Algorithm and Fuzzy logic</td>
<td>[29]</td>
</tr>
<tr>
<td>3</td>
<td>Mixed Integer Linear Programming</td>
<td>[30]</td>
</tr>
<tr>
<td>4</td>
<td>HOMER Software</td>
<td>[13]</td>
</tr>
<tr>
<td>5</td>
<td>Stochastic Method</td>
<td>[31]</td>
</tr>
<tr>
<td>6</td>
<td>Ant Colony</td>
<td>[32]</td>
</tr>
<tr>
<td>7</td>
<td>Modified Differential Algorithm</td>
<td>[14]</td>
</tr>
<tr>
<td>8</td>
<td>HOMER</td>
<td>[33]</td>
</tr>
</tbody>
</table>
6 Biomass based Power generation

Table 2. Indian Installed Capacity (MW) [37].

<table>
<thead>
<tr>
<th>Region</th>
<th>Coal</th>
<th>Gas</th>
<th>Diesel</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>RES</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>59450</td>
<td>6975</td>
<td>438</td>
<td>0</td>
<td>28012</td>
<td>1948</td>
<td>96824</td>
</tr>
<tr>
<td>Private</td>
<td>61907</td>
<td>9978</td>
<td>554</td>
<td>0</td>
<td>3120</td>
<td>35467</td>
<td>111027</td>
</tr>
<tr>
<td>Central</td>
<td>49380</td>
<td>7519</td>
<td>0</td>
<td>5780</td>
<td>1149</td>
<td>0</td>
<td>74171</td>
</tr>
<tr>
<td>Sub-Tot</td>
<td>170737</td>
<td>24473</td>
<td>993</td>
<td>5780</td>
<td>42623</td>
<td>37415</td>
<td>282023</td>
</tr>
</tbody>
</table>

As shown in Table 2, it has been determined that 13% of India's total installed capacity for electricity generation comes from renewable energy sources. 60% of energy is produced using coal. While nuclear energy technology only makes up 2.04% of the overall capacity at this time. This country-level energy resource status demonstrates the enormous benefits of installing a microgrid system based on renewable energy. India has good solar energy potential, with the majority of the country receiving 4–7 kWh per square meter every day. Over India's land area, almost 5,000 trillion kWh of energy are incident each year [38].

Table 3. Installed capacity RES MW [38].

<table>
<thead>
<tr>
<th>Small Hydro Power</th>
<th>Wind Power</th>
<th>Bio-Power</th>
<th>Solar Power</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cogeneration</td>
<td>Waste to Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4146</td>
<td>24376</td>
<td>4418</td>
<td>127</td>
</tr>
</tbody>
</table>

Table 3 shows that total power generation 22433 TWh. They are followed by Korea, Japan, Canada, Germany, France, the Russian Federation, India, and the United States of America. More over two thirds of the world's electrical power is produced by the top ten nations. More or less, fossil fuels account for two thirds of the world's energy output, with hydroelectric facilities coming in at 16.5%, nuclear power plants at 10.6%, biofuels and waste at 2.0%, and the remaining 3.3% coming from geothermal, solar, wind, and other sources [39].

7 Energy Scenario of Punjab

The availability of RES is given in Table 4.

Table 4. Resources available in various sectors of Punjab [37].

<table>
<thead>
<tr>
<th>Region</th>
<th>Coal</th>
<th>Gas</th>
<th>Diesel</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>RES</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>2630</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>2230</td>
<td>127</td>
</tr>
<tr>
<td>Private</td>
<td>3814</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>375</td>
</tr>
<tr>
<td>Central</td>
<td>660</td>
<td>263</td>
<td>0</td>
<td>208</td>
<td>914</td>
<td>0</td>
</tr>
<tr>
<td>Sub-Tot</td>
<td>7104</td>
<td>288</td>
<td>0</td>
<td>208</td>
<td>3145</td>
<td>503</td>
</tr>
</tbody>
</table>
7.1 Potential of RES in Punjab

Given that the state has a large amount of solar energy potential 4–7 kWh/Sq.mtr of solar insolation levels [44]. The government is eager to take advantage of this resource by establishing solar energy-based power projects to strengthen the state's power infrastructure and fight global warming. Punjab is mostly rich in agriculture and makes up a large portion of India's grain supply [46]. Any programme for developing energy should give careful regard to agricultural biomass, especially in states like Punjab where natural resources are scarce.

In Punjab and Haryana, the burning of paddy straw has not stopped, and the authorities in both states are powerless to stop the problem. As stated in the media, stubble burning has been outlawed by the state administration. Additionally, district officials are filing lawsuits against farmers who burn stubble on their fields under Section 144 of the Criminal Procedure Code (CrPC), which was put in place to protect law and order and prevent disturbances. Experts claim that the lack of machinery makes implementation impossible. Farmers only have 15 to 20 days between paddy harvest and the start of a new crop, thus many expensive straw-chopping equipment are needed to chop straw rather than burn it. Rural families' financial situation is problematic. Farmers are heavily indebted as a result of this. Next to Andhra Pradesh and Tamil Nadu, Punjab has the nation's most highly burdened peasantry, according to a National Sample poll Organisation (NSSO) poll. According to media reports, Punjab's rural debt is estimated to be over Rs. 35,000 crore, which has led to farmer suicides. According to the most recent report by Punjab Agriculture University in Ludhiana, almost 5000 farmers and farmworkers have killed themselves in the past ten years [40]. Many small and marginal farmers have been destroyed by their heavy debt loads and have been forced to sell or mortgage their land. Many farmers have ultimately committed suicide as a result of this. Utilising surplus agricultural biomass to generate electricity will improve the economic situation of farmers while reducing pollution and effectively enhancing the current power grid. To examine the potential uses of the aforementioned biomass for the power industry, more research is needed.

7.2 Potential biomass energy currently available

Table 5 provides information on the biomass power potential (BPP). On the basis of this Table, it is possible to determine the quantity of residues that are available for energy production.

<table>
<thead>
<tr>
<th>Group</th>
<th>Crop</th>
<th>Residue type</th>
<th>Residue production</th>
<th>Surplus residue</th>
<th>CV</th>
<th>BPP (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal</td>
<td>Rice</td>
<td>Husk</td>
<td>2.177</td>
<td>16.669</td>
<td>16000</td>
<td>2255</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Straw</td>
<td>16.332</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>Pods</td>
<td>4.887</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stalks</td>
<td>24.436</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>Cobs</td>
<td>0.148</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stalks</td>
<td>0.990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td>Straw</td>
<td>0.058</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Cotton</td>
<td>Boll Shell</td>
<td>2.128</td>
<td>5.581</td>
<td>17000</td>
<td>833</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Husk</td>
<td>2.128</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stalks</td>
<td>1.945</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Sugarcane</td>
<td>Bagasse</td>
<td>0.145</td>
<td>0.066</td>
<td>20000</td>
<td>11</td>
</tr>
</tbody>
</table>
According to reports [48], there is a 48% availability factor for rice straw in the Indian states of Punjab and Haryana. In India, 23% of the extra rice straw generated is not being appropriately used; it is either left in the fields uncollected or occasionally burned there. 83.5% of the extra rice straw is accessible in Punjab [49]. In the majority of the state, farmers prefer using wheat straw as animal feed [50]. Using the thermal properties of each residue, one may determine the overall amount of energy present in the residues. The efficiency of incineration technology was assumed to be 20% while operating 18 hours per day (6570 hours per year) in order to assess this potential. Table 5 demonstrates that with a thermal conversion efficiency of 20%.

7.3 Availability of Livestock in Punjab

The State's rural economy depends heavily on livestock. The State Government is giving the rural population's need for self-employment options and the eradication of poverty first attention. Animal husbandry operations have become more significant since they give the less fortunate members of society chances for self-employment as well as supplementary employment [41]. Cow dung and poultry waste have traditionally been used as manure, despite the fact that they have the capacity to meet our energy needs. With the help of technology, it is now possible to produce electricity using this so-called "Bio-Waste".

8 Outcome of the literature review

As per the National and International energy scenario there are various ongoing projects on RES. After reviewing literature till date, it has been found that, at present scenario researchers are focusing on the research dealing with the combination of different types of energy resources such as photovoltaic, hydro, solar, biomass, wind along with the energy storage systems around the world at present. The best combination of various energy resources depends upon the geographical location of the particular site. The important parameters that to be taken under consideration are availability of resources like (solar access, biomass, wind, hydro) and weather conditions, also the load demand of that site. Very few reports are available those deal with the hybrid systems including biomass (combustion and gasification) with other RES. This survey reveals that the biomass is cheap, readily available and having less carbon footprints as compared to the power generation from coal.

From the data discussed above it is found that RES are available in large extent in India and almost around the world. Different types of biomasses are available throughout the year which can be utilized for electricity generation by direct combustion and gasification. From literature it has been found that many of the researchers have given the mathematical modelling of different RES. There is lack of feasible configuration of a microgrid that comprises of biomass direct combustion and gasification along with the battery storage system. The whole system should be optimized in order to be more reliable with less carbon footprints. In addition, it is also observed that a comprehensive analysis based on reliability of biomass based microgrid is required to propose an effective model of the same.

9 Challenges and Future Perspective

There are many techno-economic, environmental, policy and social challenges related to type of biomass and its processing technology. Most of the local technologies for commercial
level plants like fermentation, gasification and AD are still under development in India. To import an advance technology from developed countries become costlier that decreases the economic feasibility of plant. However, India is global leader in development of AD at small scale biogas generation for cooking at domestic level. Most of the times public oppose the establishment of biomass processing plants due to smell and some other gases emissions. The waste processing plants in India are also facing the supply chain related issues. The high moisture in MSW results as failure of its processing plants. The Indian MSW has 35% to 40% of food waste that increases the moisture of feedstock. The feedstock with this high percentage of moisture is not suitable for technologies like gasification and incineration. Second problem with MSW is segregation, Most of the MSW collected in India is unsegregated that is a major problematic issue for any processing plant. The Government of India has some schemes and subsidy policies for waste to energy generation plants. But they are limited to individual technologies only, there is lack of policy for hybrid plants that uses more than one waste to energy generation technologies. Presently, a lot of research and development work is ongoing in India to develop these technologies at commercial level. In future the production of ethanol and biogas in India is going to increase prominently.

10 Conclusion

It has observed that the use of RES is fruitful. We have to use natural resources of energy and should work for the enhancement of the agriculture. Biomass is one the key component to produce the electricity.

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