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Assessment of Biomass Resources for Decentralized Power Generation in Punjab

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Abstract

The biomass is a reliable, economical, and readily available resource of renewable energy, which can be used as a fuel for power generation. This paper estimates the availability of biomass resources for power generation in Punjab. The surplus biomass generated by major crops is considered as a fuel for producing electricity. The annual production of agricultural biomass has been estimated by residue-to-product ratio method. Further, the accessibility factor has been taken into account, to evaluate the supply potential of the biomass. The results indicate that agricultural biomass can used to provide continuous and sustainable fuel supply to the decentralized power plants in the state. As the biomass is a distributed resource, therefore the power plants with capacity of 1MW to 2MW can be installed in the rural areas of Punjab, to meet the local energy needs. This will not only provide the waste disposal system for the agricultural biomass in spite of burning in the fields, but will also overcome the problems of energy deficit in the state and global warming in overall.

Keywords: Resources, Agricultural biomass, Residue Index, Accessibility, Power generation, Punjab.

1. Introduction
There has been renewed interest in biomass as a renewable energy resource worldwide, due to technological advancements related to biomass conversion and low greenhouse emissions. The advanced options available to produce electricity are

looking promising, and allow a cost effective use of biomass, by means of gasification processes. When the biomass is used to produce electricity with higher conversion efficiency, the cost of electricity is often competitive with fossil fuel power generation [1]. Agricultural crops, which are used as a major resource of biomass, include rice, sugarcane, wheat, corn, cotton, mustard, maize, groundnut and grains [2]. The agricultural biomass has been successfully used as a biomass feedstock, for power generation in various parts of the world [3-6]. But, the availability of agricultural residues depends upon the cropping intensity, productivity and type of crops grown in a region. The strength of locally available biomass resources can be utilized for the economic development of the region. Therefore, the assessment of biomass resources and their energy potential in a specific region could be helpful in the uniform growth of biomass energy in that region.

The surplus agricultural biomass can be significantly used as a fuel for power generation. It has been revealed in the earlier studies that the rice straw can produce 1600MW of electricity, by setting up decentralized power plants in Punjab, with optimal capacity of 40MW [7]. It was revealed that installation power plants using biomass would result in multifaceted benefits to the rural people of the state. First of all, the conversion of non-commercial residue into valuable by-product would fest some additional income to the farmers. Secondly, the engagement of the rural people in collection and transportation chain would generate employment. Thirdly, the decentralized power generation would result in development stimulated by assured supply of electricity in the state. But the collection and transportation of agricultural biomass are some of the critical operations, required for installation and operation of a biomass based power plants. Therefore, an effective biomass management system is required to generate electricity at a reasonable cost [8]. To find optimum location, size and cost of the biomass, the precise assessment of biomass resources is required. The present study estimates the supply potential of agricultural biomass for decentralized power generation in Punjab.

2. Methodology

2. 1 Resource Base

The resource base is defined as the annual production of the agricultural residues generated in a region. The main objective of this step is formation of the database, for estimating the supply potential of biomass for energy. The primary items of information required for the estimation of resource base are the annual production of the primary crop and the residue index. Thus, the theoretical potential, R_B is obtained by following equation:

$$R_B = R_I P \quad (1)$$

where R_I is the residue index and P is annual production of the primary crop. Data on the crop production is collected from the agricultural statistics of the region and the residue production for most commonly grown crops is readily available in scientific literature [9, 10].

2. 2 Supply Potential

The resource base of biomass in a region is subjected to the restrictions, which are introduced by alternative uses of agricultural residues as well as efficiency of residue collection procedure. The potential uses of agricultural wastes are specific to the crop residue. Therefore, the amount of the residue available for energy production can be determined, taking into account alternative applications of the residues and the collection mechanisms. The access to the crop residue from the point of view of location is called as physical accessibility and that from socio-cultural conditions is known as social accessibility. The former can be obtained from literature, while the latter is estimated from field surveys. The expression used for estimating available potential of agricultural residues in terms of the primary information, is given below;

$$S_P = F_X(L') F_S R_I (P-R_O) \text{ if } E_{VO} > E_V \quad (a)$$
$$= F_X(L') F_S R_I P \text{ if } E_{VO} < E_V \quad (b)$$
$$= 0 \text{ if } E < E_{VO} \text{ and } R_O > R_A \quad (c)\ (2)$$

where F_s is the fraction of residue accessible from socio-cultural point of view, F_X (L^*) is the fraction physically accessible, R_o is the amount of residue used for other applications, R_A is the residue available for energy and E is economic value of the crop residue.

The physical accessibility of the crop residues has been evaluated by a large number of authors [11-13]. To find the social accessibility field survey can be carried, which involves group discussions with the farmers and people of the state. The items of information required for estimating the economic value of the residues are the annual operating and capital cost of end use technology and the conventional fuel, for which it is to be substituted [14, 15].

2. 3 Energy Potential

The combustion process convert chemical energy stored in biomass into heat, mechanical power and electricity using various equipments, e. g. furnaces, boilers, steam turbines and generators. It is possible to burn any type of biomass with a moisture content of less than 50% [1]. Literatures are available citing typical size of combustion based biomass power plant from a few kW up to 100 MW with net conversion efficiency between 20% and 40% [1, 16]. The Lower heating value (LHV) is an important parameter that is used to estimate energy potential of *CRB*. Using the LHV, the energy potential is estimated as follows:

$$E_P = (S_P C_V T_E) / T \quad (3)$$

where E_P is the agricultural biomass power in Punjab, MW; T_E is the overall Thermal efficiency for biomass conversion (%), T_E is the annual operating duration in seconds and C_V is the average calorific value for all the crop residues generated in Punjab and its value is taken as 16000MJ/ton for calculation purpose. Continuous operation throughout the year is considered for assessment of power. A conservative value of T_E as 20% is considered for the present study. It was also assumed that the power plants producing electricity were operated for 18 hours on daily basis, with a total of 6570 hours in the a year.

3. Results and Discussion

3. 1 Resource Base

Using methodology described in section 2. 1, total amount of the agricultural residues generated in Punjab has been estimated and presented in Table 1. The residues generated by each crop during the year 2012/13 have been calculated by applying equation (1). It is clear that a large amount of the biomass is generated in the state on renewable basis, which can be managed to bring the state at par with developed nations. But, the quantity of residues available for energy is quite less as compared to the resource base, and it can be evaluated by considering the accessibility factor and the use of these residues for non-energy activities as discussed in the section 2. In the next section, an effort has been made to estimate the surplus biomass available for producing electricity by considering all these factors.

Table 1 Residue availability of major crops in Punjab during 2012-13

Crop	Annual Production (thousand MT)	Residue Type	Residue Availability (thousand MT)
Rice	11310	Husk	2262
		Stalks	16965
		Straw	16965
Maize	458	Cobs	916
		Stalks	916
Wheat	16100	Pods	4830
		Stalks	24100
Cotton	1940	Boll Shell	2134
		Husks	2134
		Stalks	1976
Sugarcane	563	Bagasse	185
		Leaves	28
Total			73411

3. 2 Supply Potential

It has been discovered from the study that the rice residues have no significant use at the moment. However, the wheat residues have low accessibility, as these are commonly used as animal feed in the state. The economic value for all the residues has been evaluated from the field data and it is reported to be much higher for energy purposes as compared to non-energy activities. The accessibility factor for various crop residues is specific to the type of crop and its applications in non energy activities. Finally, the survey of opinion did not reveal any social or cultural prohibitions against utilization of these residues for energy. The total supply potential of crop residues for energy has been estimated by applying equation (2) and presented in Table 2.

Table 2 Estimating supply potential of major crop residues for use as fuel in power plants

Crop	Annual Production (TMT)[a]	Residue Type	Residue Index (kg/kg)	Accessibility Factor (%)	Supply Potential (TMT)[a]
Rice	11310	Husk	0.2	83	1877
		Stalks	1.5	75	12723
		Straw	1.5	80	13572
Maize	458	Cobs	2	80	732
		Stalks	2	80	732
Wheat	16100	Pods	0.3	30	1449
		Stalks	1.5	30	7245
Cotton	1940	Boll Shell	1.1	40	853
		Husks	1.1	50	1067
		Stalks	3.8[b]	35	1470
Sugarcane	563	Bagasse	0.33	80	148
		Leaves	0.05	80	22
Total					**41890**
Sources	Ref. [15]		Ref. [10]	Ref. [11-13]	

[a] Thousand metric tons
[b] Tons per hectare with total area under cotton as 490000 hectare

3. 3 Energy Potential

By applying equation 3 and using data presented in Table 2, the total energy of the agricultural biomass generated in year 2012-13 has been found as 5667 MW. But, the biomass is a distributed resource and it has to be collected from the farms, therefore it will involve large investment in biomass management (collection, transportation etc.). It has been reported that shorter is the distance of biomass transport, lesser is the cost of biomass and lesser is the cost of bioelectricity production. Therefore, it will be economical to install decentralized power plants at village level to fulfil the local demand of electricity. Gasification power plants of 1MW to 2 MW can be installed under one roof in a modular design. If one engine/reactor is shut down for maintenance, the other reactors/engines can continue generation in the modular design, thereby continuing power supply to the jurisdictional villages.

4. Conclusion

In this paper, a methodology has been presented, for estimating the supply potential of agricultural biomass for power generation. The methodology has been tested in the state of Punjab, where the execution of various steps has been illustrated, for estimating the supply potential of agricultural biomass. A supply potential of the order of 41890 thousand metric ton was evaluated for agricultural biomass in the state. Under the assumptions made, a total of 5667 MW of electric power can be generated, by using all the biomass resources available on annual basis. Although, it may be difficult to realize in a short time frame, but it is important to recognize the technical and economical needs of biomass power plants from engineering point of view.

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