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Strategic study of crop residue across Punjab state: a case study of Punjab state

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Abstract - Crop residue is renewable resource of energy which is not only readily available in Punjab state but also posing a serious problem of its disposal. Presently, the farmers burns the surplus crop residue in the open fields for its disposal. Burning of surplus crop residue not only causes pollution but at the same time burn the potential wealth, that could be generated by its conversion into useful energy. In the present study assessment of crop residue potential and its energy potential from surplus crop residue across each district of Punjab state has been practically explored by using the residue product ratio (RPR) technique. As the crop residue has been produced from variety of crops across the state, so in this paper more realistic approach for the assessment of crop residue has been adopted depending upon practical patterns of crop residue regarding collection and storage. Ultimate and proximate analysis of the crop residue has been performed to ascertain the various parameters of crop residue as fuel. It is estimated that in Punjab state the annual production of total crop residue is 29.46 MT and total surplus crop residue as 14.53 MT as some of the crop residue has been used as home fuel, food for animals, for thatching and other uses. It is further estimated that practically around 1000MW power in the state can be generated from the surplus crop residue. This paper is based on wide range of field survey across the state to collect the sample of particular crop residue from that area where the crop is dominating. The present study can provide a vital data for the planning and installation of crop residue based power plants across the state.

Key Words:- Agro residue, Decentralized power, Strategic, Ultimate analysis

I. INTRODUCTION

Punjab, a north Indian state has made a great progress not only in agriculture but also in industrial, transport and household sectors resulting in tremendous increase in energy demand. The internal installed capacity of Punjab was 680 MW in 1970-71 which has been increased to 3620.35MW in year 2011, where as its total internal and external installed capacity has been increased to 7035.316MW. The maximum power consumption was noted in july 2011 was 9399MW, hence there was a shortage of 2363.684 MW in the state [1]. It is feared that conventional resources may not be able to meet the rising electricity demand as the annual growth rate of installed capacity during the last five years has declined to 2.85% in comparison to more than 7% during the three decades. The consumption of petroleum products in Punjab has also experienced a nominal rise. Punjab state does not have its own resources of conventional fuels. The state has to depend on neighboring states for conventional energy. Therefore, the development of the state can be jeopardized by any natural calamities not within the control of the state government, thereby threatening the sustainability of economic development [2].The state occupies 1.5 % of the geographical area of the country (India) and two- third of the food grains procured annually in the country come from this state. Cultivation area has been increased to 42.68 lakh hectares, which is 85% of the gross state area 50.36 lakh hectares. With better supply of irrigation water through canals and electric motor pumps, which is 97% of the cultivated area the foodgrain production improved to 3.16 million tones [3]. Main crops are rice, wheat, maize, cotton, oilseeds, ground nut, sugarcane, bajra, jowar, pulses and cereals barely etc. During the crop cultivation large volume of agricultural residue has been produced in the fields, It is estimated that 22.65 million tones of agro residue and agro industrial / processing waste is produced annually. But unfortunately its major part it is being burnt in the fields, which alone has a potential of producing 1500MW of electricity [4]. Beside power potential burning of 01 tonne of residue releases 3 kg of particulate, 60 kg of CO, 1460 kg of CO_2, 199 kg of ash and 2 kg of SO_2, which causes severe health problems like white cataract, asthma, cancer, lung diseases and other breathing related problems [5]. So wealth is being burned in the fields which create pollution problems in the state and decreasing the land fertility. Punjab has made tremendous progress not only in the agricultural sector but in the industrial, transport and

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household sectors also. [6-7]. To meet the supply and demand gap and to address the problem of pollution due to agro waste, state government has changed energy policy and under the (NRSE) policy 2006, government of Punjab offered a financial and fiscal incentives to add a generation capacity of 1000 MW by the year 2020 bringing the share of NRSE to the level of 10% of the conventional power. Punjab state electricity commission has issued directives under the section 108 of the electricity act 2003 for the compliance of the NRSE-2006 policy [8-9].

II. MATERIALS AND METHODS

The methodology for conducting the present study is being adopted as following:

2.1 Selection of Geographical region

Punjab is the most advanced state of India, where thermal and hydel are only two conventional sources for power generation. During 2010-11 the gross power generation from all the resources has been estimated as 13005.189 MU [1]. As at present the state does not have any major hydro potential, so thermal generation is mainly concerned. Punjab is geographically located far away from the coal mines. While exploring other sources of energy, it was noticed that some falls were available on canals in Punjab, where mini hydro plants can be constructed. Further the state has million hectares of well-irrigated & fertile land, which produces million ton of crop residues. It was felt that agro residue (biomass) based power can provide specific advantages to Punjab and it is the beginning era for setting up crop residue based power generation units in Punjab.

2.2 Data Collection

Earlier Punjab Energy development agency had conducted a door to door survey in 36 tehsils of Punjab through private agencies [5] to assess the total biomass availability, nature of available biomass, potential of power production and proposed location and rating of biomass based power plant in that tehsil. But in the present study assessment of crop residue potential and its energy potential from surplus crop residue across each district of Punjab state has been practically explored by using the residue product ratio (RPR) technique. Overall it was estimated that Punjab state has power potential of 1500MW from agro residue [4]. But by considering the low overall efficiency, it is accurately estimated as 1000MW. To harness this potential some of the plants have already being sanctioned and some are being sanctioned. The energy content of one tone of crop residue is nearly equal to the heat energy content of 0.55 tones of air dry fuel wood [10]. Sixty one percent of crop residue in country is produced from straws, remaining 39% includes sugarcane 23% stalks 11% husk and cobs are 5% [11]. The samples selected for the present study covers almost all the agro residues in the state. The present pattern of disposal of biomass has also been shown as Figure 1.

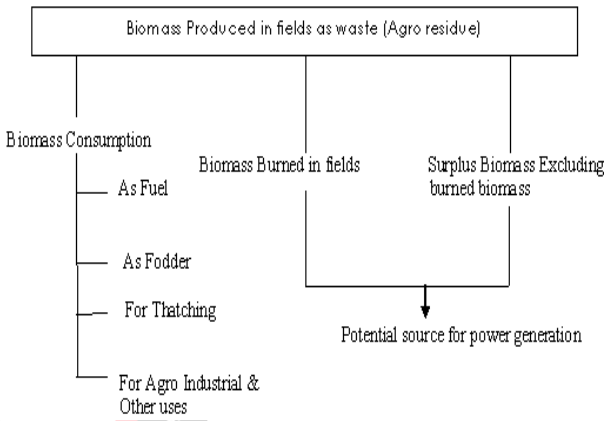

Fig.1. Biomass utilization scenario in Punjab state (India)

2.3 Data Analysis

Samples of above mentioned agro residue have been collected from fields across the state, which has been mentioned in Table 2. The proximate and ultimate analysis of the collected samples has been conducted in the research laboratories.

2.4 Thermo Chemical Conversion Process

Thermo-chemical conversion process is the biomass conversion process at elevated temperature under varied atmospheric conditions [13] and can be represented as per chemical reaction no. 1

$$CH_xO_y + n\,(0.21\,O_2 + 0.79\,N_2) \rightarrow \text{heat} \quad CO + H_2 + CO_2 + H_2O + C_xH_y + \text{Chars} + \text{Tars} + \text{Heat} \quad \ldots. \quad (1)$$

The product formation in the above reaction depends upon the quantity of air used. It is very important to define the equivalence ratio (ER) to understand the reaction mechanism. The equivalence ratio is the ratio of actual air used in the reaction to the stoichiometric air required. In the above reaction if the ER is zero i.e. the reaction takes place in the absence of air with some external heat supply, the end products are solid fuel (char) and liquid fuel (tar) and gases. The process is called pyrolysis. If ER is greater than and equal to one, the process is called combustion and the end product is flue gas at high temperature and sensible heat of flue gas is useful end product. and if ER varies between zero and less than one, the process is called gasification. The end product is gaseous fuel called producer gas. The process is performed in the reactor called as gasifier. Various conversion process and schematic power production from residue are shown as Figure 2.

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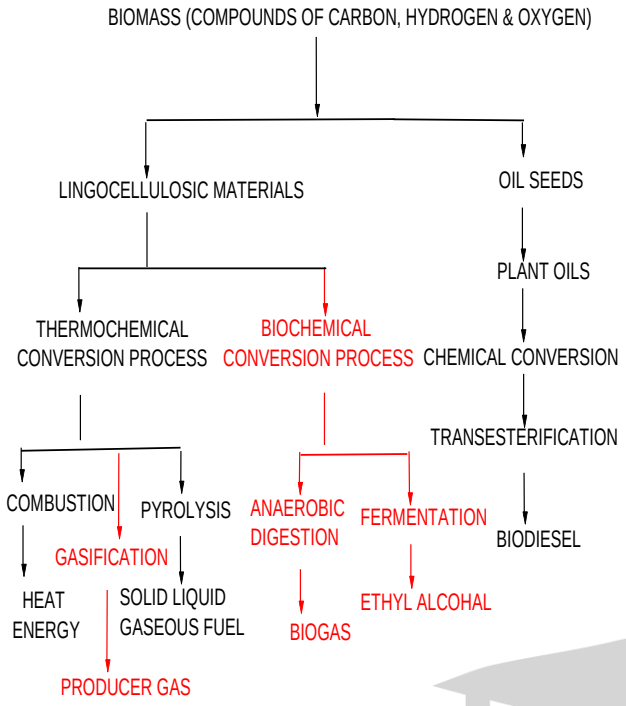

Fig.2 Biomass conversion process network

III. CROP RESIDUE AND ENERGY POTENTIAL

Energy potential from unused agro residue can be determined by multiplying the net supply potential of agricultural residue with lower heating value. Every type of biomass is having different lower heating value and same is used herewith for estimation of energy potential as Equation 2 [6].

$$Q_{ep} = \sum_{i=1}^{n} (MA_i \times LHV_i) \times n_c \quad \ldots\ldots (2)$$

Where Q_{ep} = Energy Potential (MJ/Year)

MA_i = Amount of Agricultural residue (kg/year)

LHV_i = Lower Heating value in (MJ /kg) of air-dry biomass.

n_c = Conversion efficiency

The district wise crop residue estimated in various categories has been calculated using above procedure and is given in table no;1

Table 1: Unused Crop Residue Potential (CRP) and Energy Potential (EP)

Sl. No.	District	Crop residue potential (CRP) in Thousand Ton					Energy potential (EP) in 10^{14}J				
		CRP from category A1	CRP from category A2	CRP from category A3	CRP from category A4	Total CRP	EP from category A1	EP from category A2	EP from category A3	EP from category A4	Total EP
1	Gurdaspur	695.66	36.05	14.13	96.96	**842.79**	108.19	6.01	2.82	15.23	**132.25**
2	Amritsar	1122.04	12.28	2.05	144.43	**1280.8**	174.52	2.06	0.41	22.9	**199.89**
3	Kapurthala	453.26	19.64	02.05	67.18	**542.13**	69.88	3.28	0.41	10.53	**84.1**
4	Jalandhar	654.57	49.06	04.78	99.94	**808.36**	101.22	8.20	0.95	15.76	**126.13**
5	SBS Nagar	247.47	77.21	03.53	51.73	**379.94**	38.41	12.87	0.70	8.4	**60.38**
6	Hoshiarpur	310.55	328.49	08.65	119.46	**767.16**	48.94	54.77	1.73	20.15	**125.59**
7	Rupnagar	284.81	113.34	2.05	61.4	**461.6**	44.78	18.9	0.41	10.09	**74.18**
8	Ludhiana	1216.16	15.84	00.68	169.19	**1401.87**	187.63	2.68	0.14	26.36	**216.81**
9	Firozpur	1106.71	20.31	00.68	132.74	**1260.44**	173.06	3.52	0.14	20.63	**197.35**
10	Faridkot	426.77	02.25	nil	57.00	**486.02**	66	0.39	nil	8.86	**75.25**
11	Shri Muktsar Sahib	495.77	13.85	nil	53.29	**562.91**	78.3	2.4	nil	8.28	**88.98**
12	Moga	806.84	01.75	nil	111.81	**920.40**	124.27	0.3	nil	17.38	**141.95**
13	Bathinda	582.86	23.03	nil	65.56	**671.45**	91.7	4	nil	10.19	**105.89**
14	Mansa	402.60	12.58	nil	44.63	**459.81**	63.41	2.18	nil	6.93	**75.52**
15	Sangrur	1794.84	6.39	0.91	243.61	**2045.76**	277.06	1.12	0.18	37.86	**316.22**
16	Patiala	1035.05	04.32	00.91	141.65	**1181.93**	159.78	0.72	0.18	22.03	**182.71**
17	Fatehgarh Sahib	396.41	04.20	01.71	54.90	**457.22**	61.2	0.7	0.34	8.54	**70.78**
Total Crop Residue						**14530.59**	Total Energy				**2273.98**

IV. RESULTS & DISCUSSION

It is observed from Table 1 that the district wise unused crop residue potential is Gurdaspur 842.79 X 10^3 Tonne, Amritsar (including Tarntarn) 1280.8 X 10^3 Tonne, Kapurthala 542.13 X 10^3 Tonne, Jalandhar 808.36 X 10^3 Tonne, SBS Nagar 379.94 X 10^3 Tonne, Hoshiarpur 767.16 X 10^3 Tonne, Rupnagar 461.6 X 10^3 Tonne, Ludhiana 1401.87 X 10^3 Tonne, Firozpur 1260.44 X 10^3 Tonne, Faridkot 486.02 X 10^3 Tonne, Shri Mukatsar Sahib 562.92 X 10^3 Tonne, Moga 920.40 X 10^3 Tonne, Bathinda 671.45 X 10^3 Tonne, Mansa 459.81 X 10^3 Tonne, Sangrur 2045.76 X 10^3 Tonne, Patiala 1181.93 X 10^3 Tonne, Fatehgarh Sahib 457.22 X 10^3 Tonne. The districtwise availability of crop residue has been shown in Figure 3.

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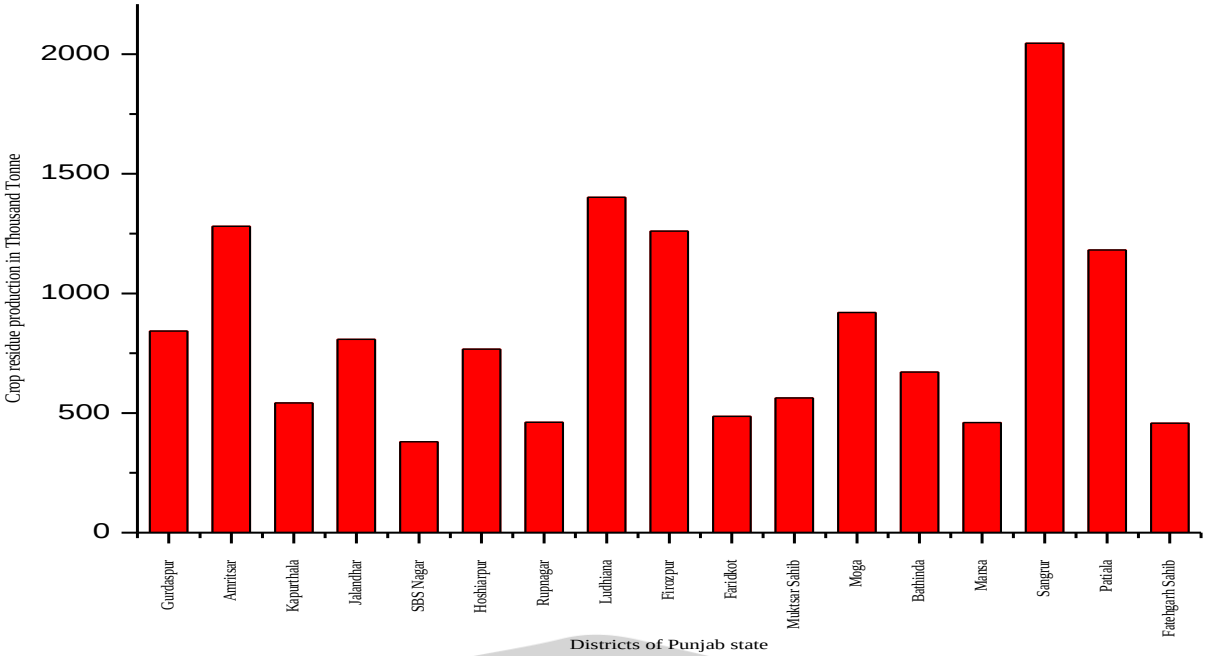
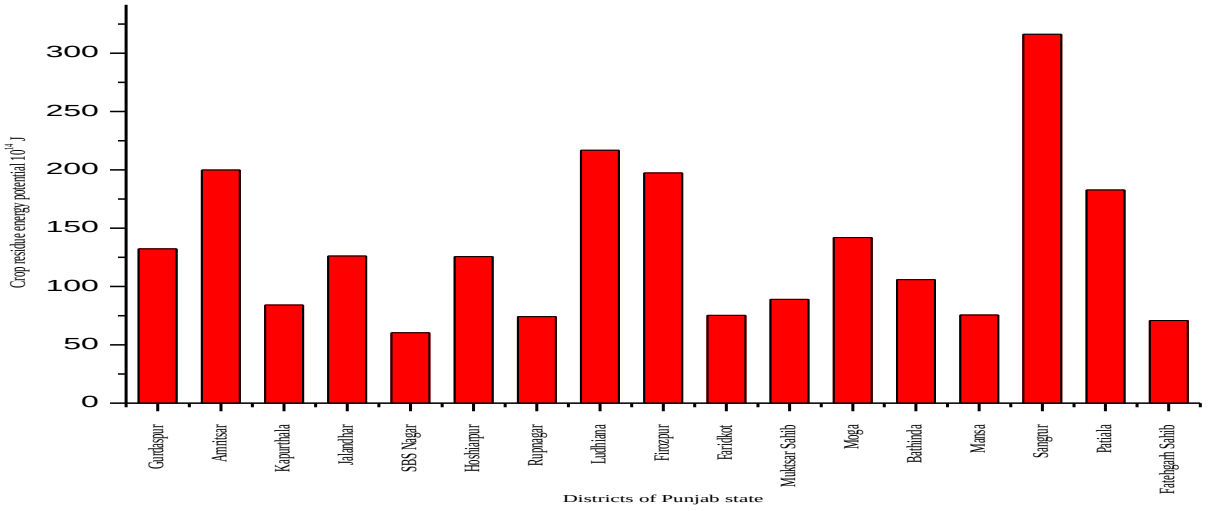


Figure 3: Availability of unused crop residue district wise

District wise distribution of unused crop residue is very important because for the designing of the new power plant, the intensity of the particular category of crop residue is very important. Depending upon the availability of particular crop residue intensity, certain design modifications can be incorporated in designing new power plant. Distribution intensity of crop residue of a particular category is helpful to calculate the category wise surplus (unused) crop residue produced across the district. It form the basis for the optimum location of the power plants in the district. As the design of the power plant depends upon nature of crop residue, so the estimation of crop residue in different categories helps in the designing of the power plant whether it is combustion based or gasification based technology.

It has been further observed from Table 1 that the district wise energy potential from unused crop residue is Gurdaspur 132.25 x 10^{14} J, Amritsar (including Tarntarn) 199.89 x 10^{14} J, Kapurthala 84.1 x 10^{14} J, Jalandhar 126.13 x 10^{14} J, SBS Nagar 60.38 x 10^{14} J, Hoshiarpur 125.59 x 10^{14} J, Rupnagar 74.18 x 10^{14} J , Ludhiana 216.81 x 10^{14} J, Firozpur 197.35 x 10^{14} J, Faridkot 75.25 x 10^{14} J, Shri Mukatsar Sahib 88.98 x 10^{14} J, Moga 141.95 x 10^{14} J, Bathinda 105.89 x 10^{14} J, Mansa 75.52 x 10^{14} J, Sangrur 316.22 x 10^{14} J, Patiala 182.71 x 10^{14} J, Fatehgarh Sahib 70.78 x 10^{14} J.



The districtwise availability of energy potential is also shown in Figure 4

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V. CONCLUSIONS

1. In Punjab state total surplus crop residue is 14530.59 x 10^3 Tonne and total potential of energy from surplus crop residue is 2273.98 x 10^{14} J. Further power potential from the surplus crop residue is 1090 MW.

2. In the categorywise production of unused crop residue and energy potential per year, the category A1 is the most important with unused crop residue 12032.37 x 10^3 Tonne (82.80 %) and energy potential 1868.35 x 10^{14} J (82.16%), category A4 on second place with unused crop residue 1715 x 10^3 Tonne (11.80%) and energy potential 270.12 x 10^{14} J (11.87%), category A2 lies on 3rd place with unused crop residue potential 740.59 x 10^3 Tonne and energy potential 5.45 x 10^{14} J and category A3 is the least important with unused crop residue 42.13 x 10^3 Tonne and energy potential 8.41 x 10^{14} J (< 01%).

3. The districtwise unused crop residue potential is Gurdaspur 842.79 x 10^3 Tonne, Amritsar (including Tarntarn) 1280.8 x 10^3 Tonne, Kapurthala 542.13 x 10^3 Tonne, Jalandhar 808.36 x 10^3 Tonne, SBS Nagar 379.94 x 10^3 Tonne, Hoshiarpur 767.16 x 10^3 Tonne, Rupnagar 461.6 x 10^3 Tonne, Ludhiana 1401.87 x 10^3 Tonne, Firozpur 1260.44 x 10^3 Tonne, Faridkot 486.02 x 10^3 Tonne, Shri Mukatsar Sahib 562.92 x 10^3 Tonne, Moga 920.40 x 10^3 Tonne, Bathinda 671.45 x 10^3 Tonne, Mansa 459.81 x 10^3 Tonne, Sangrur 2045.76 x 10^3 Tonne, Patiala 1181.93 x 10^3 Tonne, Fatehgarh Sahib 457.22 x 10^3 Tonne.

4. The districtwise energy potential from unused crop residue is Gurdaspur 132.25 x 10^{14} J, Amritsar (including Tarntarn) 199.89 x 10^{14} J, Kapurthala 84.1 x 10^{14} J, Jalandhar 126.13 x 10^{14} J, SBS Nagar 60.38 x 10^{14} J, Hoshiarpur 125.59 x 10^{14} J, Rupnagar 74.18 x 10^{14} J , Ludhiana 216.81 x 10^{14} J, Firozpur 197.35 x 10^{14} J, Faridkot 75.25 x 10^{14} J, Shri Mukatsar Sahib 88.98 x 10^{14} J, Moga 141.95 x 10^{14} J, Bathinda 105.89 x 10^{14} J, Mansa 75.52 x 10^{14} J, Sangrur 316.22 x 10^{14} J, Patiala 182.71 x 10^{14} J, Fatehgarh Sahib 70.78 x 10^{14} J.

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