ANALYSIS OF BIOMASS ENERGY POTENTIAL IN PUNJAB

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Abstract : Biomass energy is one of the renewable energy which not only a green energy but also solve out the waste disposal problem which is among the major concern issues of today's world. The biogas obtained from the biomass is rich in methane which has higher calorific value than LPG, thus a better fuel for household and even transportation purposes. This biomass energy can be converted into electricity also. This paper presents the analysis of the potential Punjab has as biomass energy producer. Punjab is among the leading producers of wheat, paddy etc. which are the good biomass sources for biomass energy. This paper presents the district wise biomass availability in Punjab and further presents a report on how much the coal and cost can be saved after installing the biomass energy harnessing system to produce electricity in Punjab.

***IndexTerms* – Biomass Energy, Coal Consumption, Crop Straw, Livestock Manure.**

I. INTRODUCTION

With the advancement of technology in order to improve the livelihood, the demand of electric power is rising at a good pace. The electric power generation is one of the concern areas. Still the thermal power generation shares the largest portion of total electricity generation the sources not only degrade the environment but also have imposed a question of meeting the current energy demand once they get consumed up all. The renewable sources have shown the potential to replace these non-renewable sources but a lot of research is needed in this regard to achieve satisfactory results. This paper estimates the potential of biomass energy in Punjab, state of India. Figure 1 shows the electric power generation in Punjab by different sources. In total power generation of 12866.30 MW in Punjab, there is still 64.55% power is being generated from coal. Renewable Energy Sources (RES) share a small percentage of 6.12% of total power generation [1].

Lybaek *et al.* focused on the deriving the environmental benefits from the use of biomass residues. Energy-and-business models had been developed for screening of relevant biomass residues for energy production [2]. Septiyadi *et al.* discussed the potential of biomass energy in Indonesia for rural electrification [3]. Gao analyzed the crop straw, livestock manure and forest resources to produce the biomass energy in Heilongjiang province of China [4]. Namuli and Pillay maximized the revenue obtained from the selling of energy obtained from the biomass [5]. Wattananoi *et al.* studied the effects of torrefaction and densification on the combustion behaviors of biomass [6]. It was demonstrated that torrefaction increases the volumetric energy density of the biomass. Wahlroos *et al.* demonstrated the potential of combined heat and power scheme in increasing the efficiency of biomass energy in electricity generation [7]. Lamula *et al.* presented a study of a biomass based energy generation plant for a South African farm making it cost-effective and reliable [8].

The total biomass energy capacity of Punjab is being estimated in this paper for a complete year. The major crops straw and livestock manure available in different districts of Punjab are analyzed separately for their share in biomass energy. The potential of biomass energy in different districts of Punjab is being presented here. Further the amount of coal power generation reduction has been computed along with the reduction in cost of energy production after employing the biogas to electricity converting plant.

The paper is organized as follows: Section I presents the Introduction, Biomass Reserves and Distribution in Punjab is being discussed in Section II, Section III depicts the Results and Conclusion is being given in Section IV.

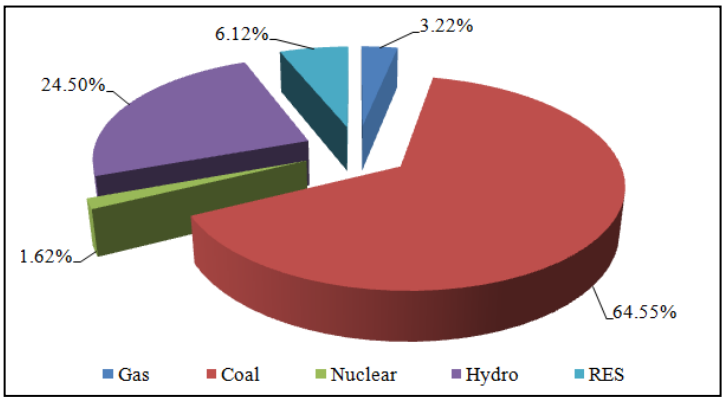

Fig. 1: Share of different sources of electricity generation in Punjab

II. BIOMASS RESERVES AND DISTRIBUTION IN PUNJAB

2.1 Crops Straw Reserves

Punjab produces many crops. The major crops along with their average yield in a year produced in different districts of Punjab are being given in Table 1 [9]. Table 2 presents the coefficient of waste content in the crops given in Table 1 [4], [10]-[12]. It can be seen from Table 1 and 2 that wheat is being produced largely in Punjab and also it has highest waste content

comparatively to other crops undertaken in this study. Thus, wheat straw is the major source of biogas production in Punjab then paddy straw and after this sugarcane bagasse.

Table 1: Major Crops Average Yield in Districts of Punjab in Tonnes per Year

District		Paddy	Wheat	Maize	Sugarcane	Potatoes	Cauliflower	Cotton
Gurdaspur	G	1057.5	919	30	1300	26.09	19.74	-
Amritsar	A	754.5	810	3	180	129.212	13.229	-
Taran Tarn	TT	750	850	4	-	21.077	2.067	1.95
Kapurthala	K	690	480	11	180	184.026	10.152	-
Jalandhar	J	882	793	35	540	504.242	-	-
Nawan Shahar	NS	346.5	348	57	280	55.11	-	-
Hoshiarpur	H	391.5	661	241	830	410.781	25.422	-
Rupnagar	R	220.5	253	76	100	20.99	2.447	-
Mohali	MH	190.5	227	24	60	31.7	6.715	-
Ludhiana	L	1699.5	1276	7	130	138.008	12.43	-
Ferozepur	FP	1431	1850	-	60	22.78	-	194.73
Faridkot	FK	613.5	563	-	-	7.97	1.78	28.74
Muktsar	MS	648	957	-	60	4.07	-	168.36
Moga	MO	1117.5	887	-	-	145.904	3.52	4.53
Bathinda	BT	655.5	1166	-	-	148.583	1.752	309.6
Mansa	MA	474	830	-	-	3.928	0.919	178.8
Sangrur	S	1777.5	1472	-	150	8.33	9.64	18.18
Barnala	BN	697.5	572	-	-	22.146	-	20.67
Patiala	P	1309.5	1141	-	150	105.005	14.224	-
Fatehgarh Sahib	FS	549	417	-	150	98.412	15.82	-
Total		**16255.5**	**16472**	**488**	**4170**	**2088.36**	**139.857**	**925.56**

Table 2: Coefficients of Waste Content in Different Crops

Crops	Paddy	Wheat	Maize	Sugarcane	Potato	Cauliflower	Cotton
Coefficient	1	1.1	2	0.32	1	0.53	0.0081

2.2 Livestock Manure Reserves

Punjab has a large livestock resource. The various major cattle in the different districts of Punjab are given in Table 3 [13]. In Table 4 the average manure generated per livestock taken under consideration in this paper during the feeding period in kg has been shown [4], [14]-[15]. It can be seen from Table 3 that Punjab has large number of buffaloes then cows and sheep. Thus, there is very high potential of biomass energy in Punjab in respective of livestock manure.

III. Result and Discussion

3.1 Crop Straw Biomass Energy Potential

Table 5 represents the energy content in per kg of crop waste [4], [16]-[18]. We can see that cauliflower has the highest energy content among the crops given here but due to less cultivation of cauliflower as given in Table 1, the total energy production is not too great. But sugarcane, wheat, paddy and potato have a very great potential of biomass energy in Punjab. It has been considered that 70% out of the total crop waste is available to get converted into biomass energy. So, to compute the biomass energy content in the various crops straw, first obtain the amount of total crop straw by multiplying the crop yield given in Table 1 with the coefficient of waste content of respective crop as given in Table 2. Then take 70% of the total straw computed considering 30% of straw is not collected. Multiply the computed term with the per kg energy content of the respective crops straw as given in Table 5 to determine the biomass energy potential of the various crops in the various districts of Punjab. This has been shown in Fig. 2. It can be seen that Ferozepur, Sangrur and Ludhiana have the greatest biomass energy potential. It can also be seen that wheat and paddy have the major potential of biomass energy in Punjab. It has been shown in Table 6 that Punjab has a potential of 1,05,177 MWh biomass energy generation annually with the help of crop wastes. Figure 3 presents the district wise total biomass energy potential based on crop waste. The crop wise annual potential of biomass energy in Punjab has been shown in Fig. 4. Wheat straw can contribute nearly 51 GWh of energy annually and paddy straw can provide nearly 40GWh of annual energy to the residents of Punjab.

Table 3: Number of Livestock in Districts of Punjab

District		Cow	Buffaloes	Sheep	Goat	Horses	Mules	Donkeys	Pigs
Gurdaspur	G	222018	321603	3688	17113	4834	420	170	934
Amritsar	A	178084	352886	3625	14711	3060	225	250	690
Taran Tarn	TT	125771	343360	7003	13153	1868	102	501	1123
Kapurthala	K	67866	127611	527	5624	516	11	23	356
Jalandhar	J	138123	249433	2912	16662	1512	126	66	1430
Nawan Shahar	NS	51388	118452	527	6225	411	98	61	243
Hoshiarpur	H	160162	248632	1255	17392	1985	185	135	532
Ropar	R	60631	148553	109	5577	436	105	27	1290
Mohali	MH	38403	148437	7863	6978	513	104	37	3590
Ludhiana	L	203980	467439	3478	23924	3116	778	263	8064
Ferozepur	FP	278817	472677	32509	35501	2054	483	160	2007
Faridkot	FK	69367	124006	5614	16151	1485	142	61	295
Muktsar	MS	114535	160123	14746	32391	2054	413	450	745
Moga	MO	108267	225310	3563	15453	1621	126	26	984
Bathinda	BT	122361	259111	7587	34038	1579	320	123	416
Mansa	MA	78943	249688	8781	14722	1155	270	118	1459
Sangrur	S	167385	490491	7968	21860	2030	592	133	1696
Barnala	BN	60744	172390	2640	8739	921	222	144	752
Patiala	P	115637	335164	13268	15196	1197	292	161	3241
Fatehgarh Sahib	FS	65232	144368	871	5862	513	150	0	2374
Total		**2427714**	**5159734**	**128534**	**327272**	**32860**	**5164**	**2909**	**32221**

Table 4: Total Manure per Livestock during the Feeding Period in kg

Cow	Buffalo	Sheep	Goat	Horse	Mule	Donkey	Pig
5475	5756	95	92	5237	4050	3092	720

Table 5: Energy Content in per kg of Crop Waste

Crop Waste	Paddy	Wheat	Maize	Sugarcane	Potato	Cauliflower	Cotton
Energy in kWh	3.502	4.082	4.319	4.247	4.319	5.966	2.551

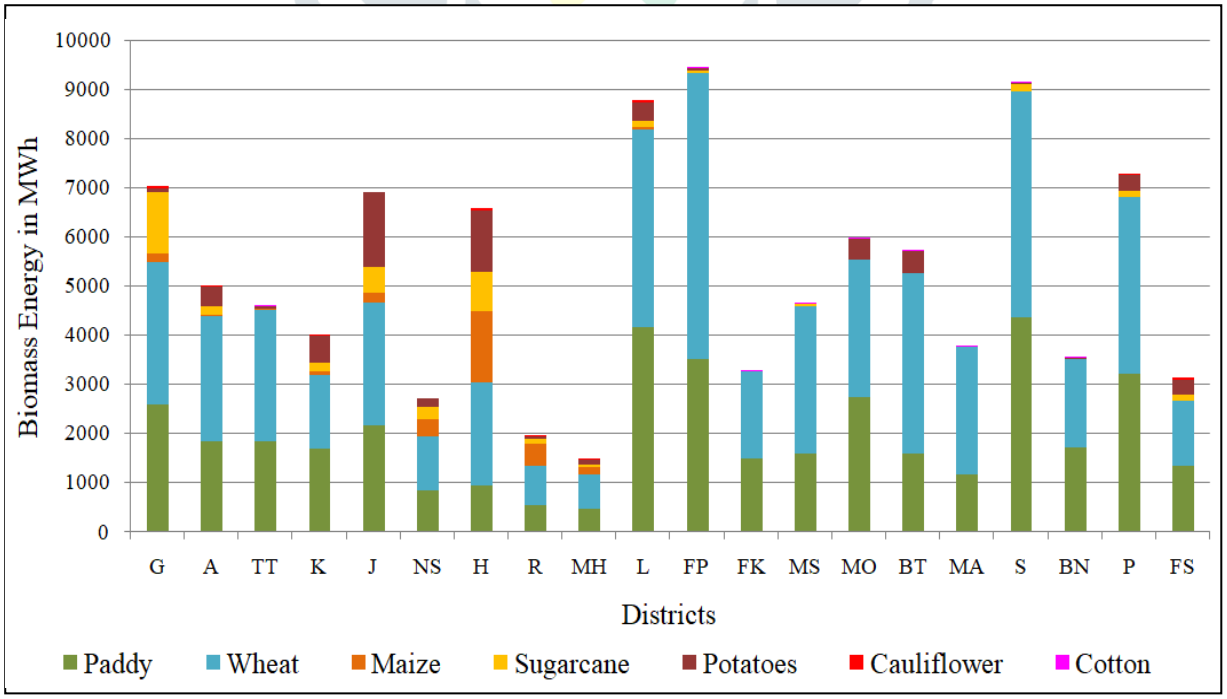

Fig. 2: Crop availability based annual potential of biomass energy in different districts of Punjab

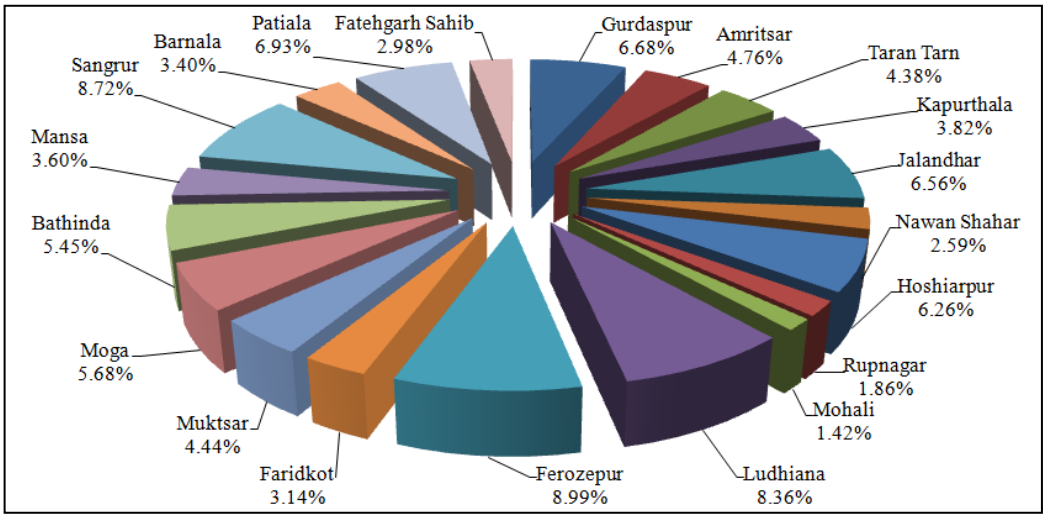

Fig. 3: District wise share of total biomass energy potential based on locally produced crop straw in Punjab

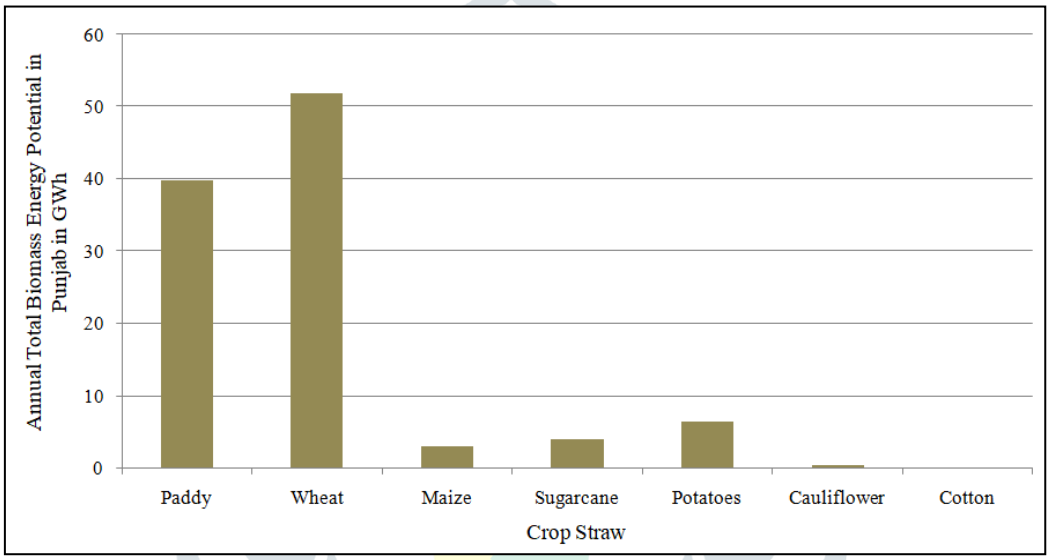

Fig. 4: Crop based annual total biomass energy potential in Punjab in GWh

Table 6: Annual Total Biomass Energy Potential from various Crop Straws in different Districts of Punjab

District	Energy in MWh	District	Energy in MWh
Gurdaspur	7021.596	Faridkot	3301.973
Amritsar	5004.831	Muktsar	4668.312
Taran Tarn	4602.731	Moga	5976.373
Kapurthala	4016.761	Bathinda	5729.361
Jalandhar	6904.468	Mansa	3787.266
Nawan Shahar	2720.865	Sangrur	9173.549
Hoshiarpur	6582.354	Barnala	3574.981
Rupnagar	1959.298	Patiala	7288.075
Mohali	1493.384	Fatehgarh Sahib	3131.752
Ludhiana	8787.552	**Total**	**105177**
Ferozepur	9451.529		

3.2 Livestock Manure Biomass Energy Potential

Table 7 presents the energy content in per kg of different livestock manure. To get the values of total manure throughout the feeding period of different cattle, multiply the total available number of cattle in different districts of Punjab given in Table 3 with the manure generated per livestock given in Table 4. Here also it is being considered that 70% of the total manure has been collected. So, take 70% of the values calculated above. Now, to get the total biomass energy potential in the different districts due to different cattle, multiply the respective total collected manure throughout the feeding period with the figures given in Table 7.

Table 7: Energy Content in per kg of Livestock Manure

Manure	Cow	Buffalo	Sheep	Goat	Horse	Mule	Donkey	Pig
Energy (kWh)	3.845	4.244	4.318	4.318	4.318	4.318	4.318	1.415

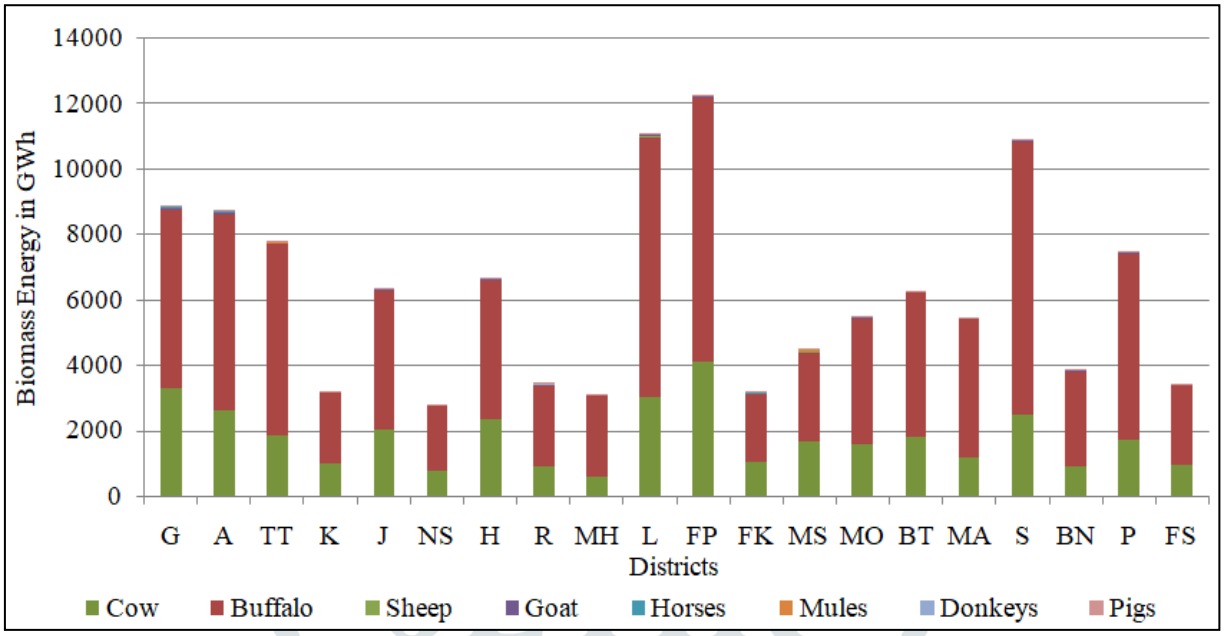

Fig. 5: Livestock manure availability based annual potential of biomass energy in different districts of Punjab

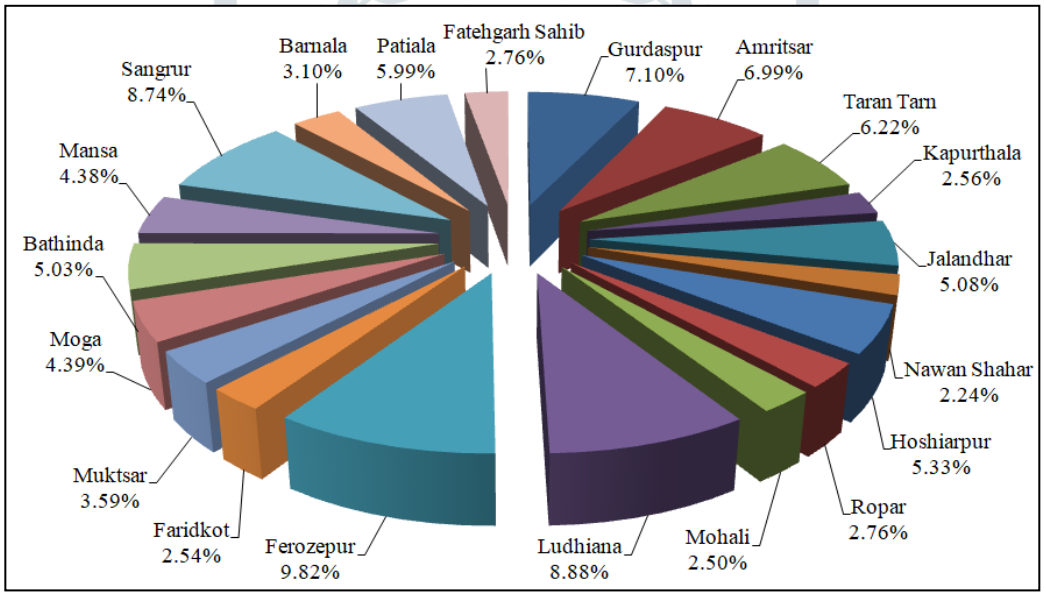

Fig. 6: District wise share of total biomass energy potential based on locally available livestock manure in Punjab

Figure 5 shows the annual potential of various livestock manure based biomass energy available in different districts of Punjab. Here also it can be seen that Ferozepur, Sangrur and Ludhiana can be the leading producers of biomass energy in Punjab. From Table 8 which shows the total biomass energy potential in different districts of Punjab based on livestock manure during a year, it can be seen that there is 1,24,767.22 GWh potential of biomass energy is available in Punjab annually. Figure 6 shows the percent share of total annual biomass energy potential based on livestock manure in different districts of Punjab. Based on the type of livestock manure, the total biomass energy potential in Punjab has been presented in Fig. 7 which shows that cows and buffaloes manure can be the main source of biomass energy in Punjab having annual potential of nearly 35,000 GWh and 89,000 GWh respectively.

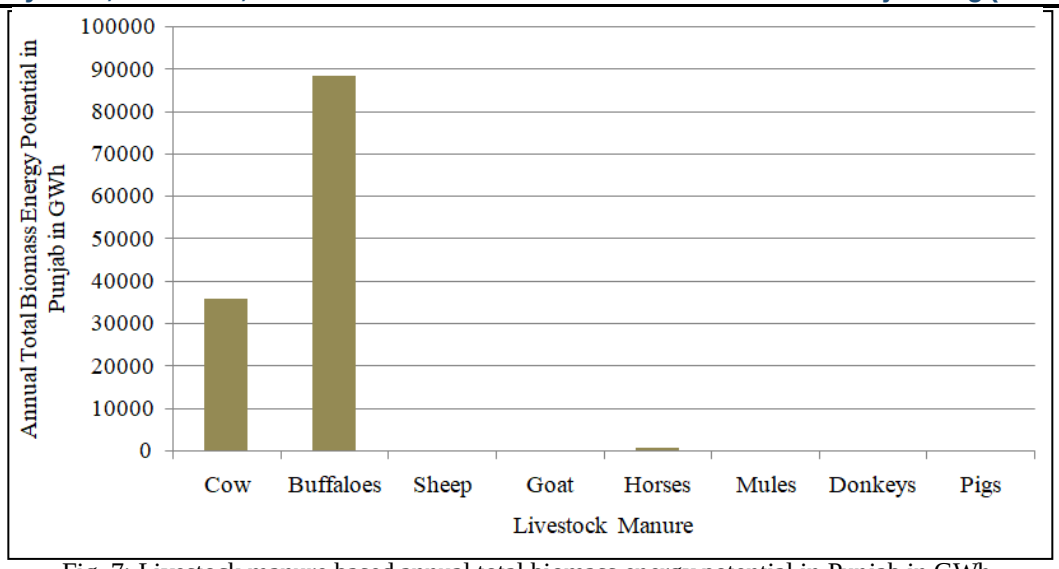

Fig. 7: Livestock manure based annual total biomass energy potential in Punjab in GWh

Table 8: Annual Total Biomass Energy Potential from various Livestock Manure in different Districts of Punjab

District	Energy in GWh	District	Energy in GWh
Gurdaspur	8860.77	Faridkot	3174.81
Amritsar	8717.72	Muktsar	4481.42
Taran Tarn	7766.76	Moga	5481.67
Kapurthala	3192.70	Bathinda	6275.89
Jalandhar	6333.24	Mansa	5463.29
Nawan Shahar	2793.10	Sangrur	10904.14
Hoshiarpur	6652.25	Barnala	3865.34
Rupnagar	3444.64	Patiala	7469.68
Mohali	3120.66	Fatehgarh Sahib	3443.47
Ludhiana	11073.72	**Total**	**124767.22**
Ferozepur	12251.94		

3.3 Electricity Generation from the available Biomass Energy

As per the current energy demand in Punjab, the anticipated requirement of electrical energy in the year 2018-2019 is 6,02,900 GWh [19]. As from the Fig. 1, the coal power generation share is 64.55%. Thus, the demanded electrical energy supplied by the coal power plants in Punjab throughout the year is being given in Table 9. As estimated in Sections 3.1 and 3.2, the total biomass energy potential available in Punjab throughout the year is also being given in Table 9.

Table 9: Coal Consumption and Cost Savings Estimation

Total electrical energy requirement throughout the year in Punjab	6,02,900 GWh
Electrical energy demand supplied by coal power plants in Punjab throughout the year	3,89,171.950 GWh
Total biomass energy potential in Punjab throughout the year	1,24,872.397 GWh
Total electrical energy converted from the biomass available in a year in Punjab	43,705.339 GWh
Savings in coal consumption throughout the year	5.353 million tonnes
Savings in the cost in coal consumption in each year	18.202 billion INR

Now, this total biomass energy can be harnessed instead of coal energy using gas turbine to generate the electricity. Generally, the efficiency of the gas turbine is nearly 30-40%. Thus, taking the efficiency to be 35%, the electrical energy potential from the available biomass energy is also being given in Table 9. Nearly 7.25% of total energy demand can be fulfilled using biomass energy, thus curtailing the share of coal energy generation to 57.30%. It has been computed that nearly 5.353 million tonnes of coal can be saved in a year. Since, the biomass energy is free of cost, thus the operating cost of electrical energy derived from biomass is almost negligible. As on the 15th June, 2019, the coal cost was 3,400 INR per ton [20]. Nearly, 18.202 billion INR can be saved annually if the electrical energy is harnessed from the biomass in Punjab.

IV. Conclusion

In this paper the biomass energy potential in the different districts of Punjab has been estimated. The crop straw and livestock manure reserves are presented separately. From the above study it can be concluded that Punjab has a very high potential of biomass energy. It has been shown that there is considerable reduction in the share of energy supplied by coal combustion if biomass energy has been used to generate electricity. It is also being shown that a large amount of coal can be saved. This will not only conserve coal resource but also reduce the pollution occurring due to combustion of coal. Further, annual cost savings due to negligible operating cost of biomass to electrical energy conversion process has been computed if the estimated amount of biomass energy has been utilized instead of coal energy. In this paper, the forest residues are not being considered which can also be considered as biomass energy source.

V. Acknowledgment

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