Prospects of Bioenergy Generation in Indian State Punjab-An Evaluation

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Abstract : In this study an evaluation has been done to identify the prospects of bioenergy generation in agricultural rich state Punjab. The evaluation is focused only on the organic waste of unused livestock dung available in state. The state is among the larger livestock producers and consequently greater dung production. Large animals are major contributor of dung production being 93% of 19th livestock population and produces 62886 million-kg/ year of dung. This dung has potential to turn out 6591 million-m^3 / year of biogas, which further carries the capability to generate bioenergy of 11934 million-kWh/ year. To present the sustainability of this bioenergy prospects in Punjab, livestock population of 18th census has also been evaluated and results are in concurrence. Thus evaluation explores the possibilities of immense bioenergy generation in Punjab.

Index Terms – animal dung, biogas, bioenergy, livestock, electrical energy.

I. INTRODUCTION

An agricultural country, India has enormous possibilities of biomass based renewable energy resources. Bio residue available as woody waste, crop production, vegetation, agro waste and organic waste like human excreta, animal excreta and sewerage waste are included in biomass sources and named as bioenergy source. The vital sub sector of Indian agriculture economy is livestock sector, which is one of the largest in world with present (19th census) population of 512.05 million and has been contributing a major role in the Indian economy [1]. The livestock are domestic animals raised in an agriculture setting to supplies like food products, wool and labour. The main source of income for Indian people is agriculture and allied occupations [2-3]. Most of Indian state's population lives in rural areas and preferred main source of livelihood is keeping of livestock in houses or farms. In most of states about two third of population is involved in dairy farming; consequently the livestock population has been increased in some prominent states with 5-15% rise from previous 18th livestock census. As per latest 19th census report of Indian livestock, animal population has increased significantly in some Indian states like Punjab, Assam, Sikkim, Meghalaya, Uttar Pradesh, Bihar, Chhattisgarh and Gujarat. Census depicts that Punjab is an progressive agricultural state and projecting 10% increase in livestock population and selected for evaluation of prospects of livestock dung based bioenergy generation.

II. INDIAN STATE-PUNJAB AND LIVESTOCK

Punjab state is spread over an area of 50362 square kilometres, and is located between 29º 33´ to 32º 32´ N latitude and 73º 53´ to 76º50´ E longitude, and contributes 1.6% of geographical area of India. Administratively, the state is divided into 5 divisions, 22 districts, and further tehsils, developmental blocks, and villages. Punjab being agriculture dominated state livestock plays a vital role in Indian and state's farming. Milk and meat are the two primary productions from livestock and farm yard manure, wool, dung are the secondary products. Punjab is among the leading Indian states for milk production and it continues to grow at a fairly high rate. Milk production is very important part of the agricultural economy in the state of Punjab. Dairy farming is quite popular among small and marginal farmers and big source of income for large farmers [4]. The two third of livestock output stand in name of dairy farming Dairying accounts for more than two third of the livestock output and is largely responsible for the rising importance of the livestock sector in the state and country.

III. ANAEROBIC DIGESTION- AN ENERGY CONVERSION METHOD

Anaerobic digestion is one among the many energy conversion techniques applied for conversion of organic waste specially dung to bioenergy. The reason for popularity of this technique is due to high efficiency and appropriateness for this conversion. Animal dung characteristics dependents on geography and type of animals but in wider terms dung has large moisture content, total solids and capacity of buffer. Dung from cows and buffaloes has about 80-90% of moisture in wet form, can be converted into biogas and later on to bioenergy through an efficient and appropriate bioconversion process [5]. Anaerobic digestion converts the energy stored in dung into biogas, then later into electrical energy. In the presence of anaerobic environment the organic waste is degraded with movement of microbes and transforms this waste into biomass and biogas which is a mix of methane gas, carbon dioxide gas and some traces of gases. There are multiple stages of anaerobic digester system like dung collection & handling, pretreatment, anaerobic digestion, recovery of biogas, usage & handling. The collected dung is mixed with required amount of water and may need some pretreatment such as screening, grit removal, mixing and flow equalization. Dung is kept in anaerobic digester for 21 days and biogas formed and bubbles at the surface and a pipe is fitted for collection of gas. The gas in pipe is combusted in combustion engine and generates bioelectricity. Normally the biogas composition is 50-75% methane, 25-50% carbon dioxide, hydrogen sulphide and ammonia. The higher heating value of biogas is from 16-25 MJ/ m^3 and the electrical energy content of biogas is 5-7 kWh/ $m^3$of biogas depending on the gas composition and biogas yield of 0.04 m3/ kg [6].

IV. MATERIALS AND METHODS

4.1 Collection of Livestock Population

The data of livestock population of Indian State Punjab has been collected from 19th livestock census and 18th livestock census all India report and Department of Animal Husbandry and Fisheries, Punjab. To evaluate the total livestock dung generation for biogas production, theses livestock species are categorized into large animals, small animals, pigs, poultry and other species are neglected for evaluation being very less in count. The large animals include buffalo and cows, small animals include sheep and goats only, pigs and poultry are considered separately [7].

4.2 Computation of Animal Dung

For calculation of total available quantity of animal dung per day or year for the livestock species discussed above, the given population has been studied. In large animals the body weight is high and estimated average dung per animal per day being 5-6% of body weight is 10-20 kg. Similarly for small animals being comparatively less body weight than large animals, the average dung production per day 4-5% of body weight and taken as 2 kg. Pig average dung production per day is 5-7% of body weight and taken as 4 kg, poultry birds per day dung production is 3-4% of body weight and taken as 0.1 kg. In the present study, quantity of dung generated by enlisted species was calculated by assuming livestock weights as 250, 40, 80 and 1.5 kilograms for cows & buffaloes, sheep & goats, pigs, and poultry birds respectively, measured in kilograms for the average domesticated breeds in India. Correspondingly, average standard values of 22.5 kg per day for large animals, 1.6 kg per day for small animals, 2.7 kg per day for pigs, and 0.045 kg per day for poultry are considered [8]. The total available total quantity of dung per day is calculated by taking the product of number of animals and dung production of each animal on per day basis.

4.3 Evaluation of Bioenergy Generation from Animal Dung

For evaluation of bioenergy potential from animal dung the determination of biogas potential is prerequisite. To generate bioelectricity from biogas many technologies are in practice. In a controlled combustion chamber the mechanical energy available from chemical energy of combustible gas methane is converted in heat engine. These heat engines are gas turbines and combustion engines. For generation of power this mechanical energy is converted to electrical energy. The production of biogas dependents on: type of animal, weight of animal, dung availability and proportion of total solids. During collection, dung is also wasted and varying availability of dung is another issue which effects the efficient collect process. For generation of biogas per unit uniform pattern of dung collection should be adopted and standardized [9-10]. The potential of biogas production from dung, the quantity of unconverted raw energy in biogas and potential of energy generation from the biogas was calculated as shown in following equations:

$$PB = AQD * TS * CA * EBTS \quad \ldots (1)$$

$$E_{biogas} = \text{Energy Content}_{biogas} * m_{biogas} \quad \ldots (2)$$

$$e_{biogas} = E_{biogas} * \eta \quad \ldots (3)$$

Where, PB = Potential of biogas (theoretical) in m^3 per year, AQD = Accumulated quantity of animal dung in kg per year, TS = Ratio of total solids of dung, CA = Coefficient of Availability, EBTS = Quantity of estimated biogas in m^3 per kg TS, Energy_{biogas} = Calorific value of biogas in kWh per m^3, m_{biogas} = Amount of biogas produced per year in m^3 per year, e_{biogas} = Quantity of generated electricity in kWh per year, E_{biogas} = Unconverted raw energy in biogas in kWh per year, η = Overall efficiency of the conversion of biogas to electricity (%).

For this research, an assumption of TS value is 25% for large & small animal's dung, 29% for pigs and poultry. Here EBTS for large, small, and pigs-poultry was 0.6, 0.4, and 0.8 m^3 per kg TS respectively. Coefficient of availability was assumed as 70% for large dairy animals, 20% for small ruminants, and 60% each in case of waste generated from commercial piggery and poultry industries. The type of dung is important for deciding the proportion of methane content in biogas. Many studies indicate that, during the anaerobic digestion of cow dung, on an average biogas recovered constitutes 50–70% methane. Methane generated from small animals dung is lesser at 40% to 50%. Methane content recoverable from poultry and swine dung on an average ranges between of 50–70% and 60%.

In present study, 60% and 45% methane content was considered as likely to be generated from large animals, pigs, poultry and small animals respectively as per expected Indian norms. The heat conversion was 90% of total methane harvested from raw material and taken as heat conversion efficiency in boiler, by assuming that calorific value of methane is 36 MJ per m^3. For calculation of potential of Bioelectricity generation from biogas, Equation 2 was utilized. In large turbines η is considered between 35–42% and in small generators it is 25%. By using Equation 3, quantity of E (biogas) is calculated. Energy content biogas is assumed to be 6 kWh per m^3 by considering 21.5 MJ per m^3 biogas as calorific value.

IV. RESULTS AND DISCUSSION

4.1 Livestock Population 19th and 18th Census

The backbone of bioenergy generation is the strength of livestock population who are major source of dung production which further used for biogas production. Table 4.1 presents the livestock population

Table 4.1: Livestock population

Punjab Districts	19th Livestock				18th Livestock			
	Large Animals	Small Animals	Pigs	Poultry	Large Animals	Small Animals	Pigs	Poultry
Amritsar	530970	18336	690	255153	428990	13405	686	264407
Barnala	233134	11379	752	771765	203589	11778	502	799756
Bathinda	381472	41625	416	265030	436481	68130	1135	274642
Fatehgarh Sahib	209600	6733	2374	698446	216082	7697	1123	723778
Faridkot	193373	21765	295	136826	172514	18696	291	141788
Ferozpur	751494	68010	2007	211336	600725	86939	810	219001
Gurdaspur	543621	20801	934	4354644	431380	14997	318	4512584
Hoshiarpur	408794	18647	532	885097	361086	16770	636	917198
Jalandhar	387556	19574	1430	441457	333762	13240	1574	457468
Kapurthala	195477	6151	356	204431	195015	4457	311	211845
Ludhiana	671419	26722	8064	3070679	668535	21171	4800	3232293
Mansa	328631	23503	1459	126427	286893	37037	781	128569
Moga	333577	19016	984	96846	342789	15996	1081	101943
Mukatsar	274658	47137	745	283438	243182	46823	422	298355
Patiala	450801	28464	3241	1324211	429409	27708	4131	1401281
Ropar	209184	5686	1290	336804	190609	6793	744	350837
SAS Mohali	186840	14841	3590	1025930	175718	12571	2727	109677
Sangrur	657876	29828	1696	1989170	631436	37192	2923	210466
SBS Nagar	169840	6752	243	123328	170786	4653	218	128466
Taran-Taran	469131	20156	1123	193058	370103	26277	441	231062
Total	**7587448**	**455806**	**32221**	**16794076**	**6889084**	**492330**	**25654**	**22122484**

4.2 Evaluation of Bioenergy Generation from Dung

Table 4.2: Bioenergy Generation from 19th and 18th Census

Punjab Districts	19th Census			18th Census		
	AQD (M-kg)	PB (M m^3)	Bioenergy Generation (M-kWh)	AQD (M-kg)	PB (M m^3)	Bioenergy Generation (M-kWh)
Amritsar	4376	459	831	3536	371	672
Barnala	1935	203	368	1692	178	322
Bathinda	3162	330	598	3630	378	685
Fatehgarh Sahib	1739	183	331	1792	188	341
Faridkot	1603	167	303	1430	149	270
Ferozpur	6217	650	1176	4989	520	941
Gurdaspur	4549	479	868	3626	383	693
Hoshiarpur	3383	355	643	2991	314	568
Jalandhar	3203	336	608	2758	289	524
Kapurthala	1613	169	306	1608	169	306
Ludhiana	5588	587	1064	5560	585	1059
Mansa	2716	284	514	2381	248	450
Moga	2753	288	522	2827	296	536
Mukatsar	2289	238	431	2030	211	382

Patiala	3744	393	711	3570	374	678
Ropar	1728	181	328	1576	165	299
SAS Mohali	1563	164	297	1455	152	276
Sangrur	5455	572	1037	5214	546	989
SBS Nagar	1401	147	266	1408	148	267
Taran-Taran	3869	405	734	3059	320	580
Total	**62886**	**6591**	**11934**	**57131**	**5984**	**10837**

Table 4.1, the 19th livestock census presents that large animal's population is 7587448, which is 93.6% of total livestock population which are bulk producer of dung. Similarly 18th livestock census presents that large animal population is 6889084, which is again about 92% of total livestock population. These figures are presenting the growth trends of large animal's population, and predict, the increasing trends in coming years. Consequently table 4.2, the AQD has increased from 57131 M-kg to 62886 M-kg from 18th to 19th census, and biogas potential has augmented from 5984 M-m^3 to 6591 M-m^3. These trends are showing the consistency in biogas production which is the most important availability for bioenergy generation. Thus the bioenergy generation augmented from 10837 M-kWh in 18th census to 11834 M-kWh in 19th census, which is about 9% increase in generation.

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