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Perspective of Estimated Energy Generation from Livestock Dung for an Indian State Punjab

Gagandeep Kaur [1], Yadwinder. Singh. Brar [2] , D. P. Kothari [3]

[1]*Department of Electrical Engineering, I. K. Gujral Punjab Technical University Main Campus, Jalandhar, India*
[2]*Department of Electrical Engineering, I. K. Gujral Punjab Technical University Main Campus, Jalandhar, India*
[3]*Dean (R & D), J. D. College of Engineering & Technology, Nagpur, India*

Abstract – *In this paper an investigation to access the available livestock dung based renewable energy source has been carried out for the Indian state Punjab. Punjab being an agriculture state has enough livestock population and correspondingly livestock dung. Estimation shows that state has 8.1 million livestock population and from that 62886 million kg of dung is produced every year. Assessment presents that the dung has an immense potential to generate 11.9 TWh of electrical energy per year through anaerobic digestion process of biogas production. About 25% of this dung is used for power generation, family type biogas plants, manure and as biofuel. The leftover of this dung is considered as waste and leads to environmental pollution. Study supports that energy production from this resource could be beneficial to meet the growing power demand of state and will help in waste management.*

Keywords: *Animal dung, Biogas, Electrical energy, Livestock, Punjab*

I. INTRODUCTION

India being an agricultural country has an immense potential of biomass based renewable energy resources. Biomass is defined as bio residue available by wood, water based vegetation, by product of crop production, organic waste and agro industries waste. The organic waste based biomass includes livestock dung, human excreta and sewerage waste. India's livestock sector which is one of the largest in world with population 512.05 million has been playing a predominant role in the Indian economy and is a vital sub sector of the agriculture [1]. The livestock are domestic animals raised in an agriculture setting to supplies like food products, wool and labour. In Indian states agriculture and allied occupation are the main source of income for the people [2-3]. About 66% of the state's population lives in rural areas and livestock is one of the major sources of livelihood for small farmers. 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 livestock census [4]. The Indian livestock population has increased significantly in latest 19th census in some states like Assam, Gujarat, Uttar Pradesh, Punjab, Bihar, Sikkim, Meghalaya, and Chhattisgarh. Punjab being an agriculture state of India and having about 10% increase in livestock population is a progressive state and is preferred for perspectives of livestock dung based power generation [1]. Apart from the prominent contribution of livestock in milk, meat, eggs and its byproducts, the livestock dung has already made contributions in some sectors of society and appropriate utilization of it may do wonders. The livestock dung based biomass is another source of renewable energy and it is produced when biomass is subjected to biological gasification. The undigested remains of taken food stuff being expelled by animal species are defined as animal dung. It is a mixture of 3:1 ratio of feces and urine and mostly consists of cellulose, hemicelluloses and lignin. In India, dung is also used as agriculture co-product like bio-fertilizer, manure, bio-pesticides, pestrepellent and energy source.

1.1 Livestock Scenario

A livestock revolution has taken place in India over the last decades. Demand for livestock supplies increased rapidly, leading to exceptional growth in the livestock sector. In India livestock forms an important constituent of an economy in general and that of agriculture sector in particular. Numerically, the livestock wealth of the country is highly impressive. As per 19th livestock census, the total livestock population of country is consisting of Buffalo, Cattle, Goat, Sheep, Pig, Horse and Pony, Donkey, Mule, Camel, Mithun and Yak. In 19th livestock census the total livestock population is 512.05 million which includes 21.23% buffaloes, 37.28% cattle, 26.40% goats, 12.71% sheep and 2.01% pigs and 0.37% are others as shown in figure 1. In Indian state Punjab, agriculture and allied occupation are the main source of income for the people [5]. Livestock is one of the major sources of livelihood for small farmers and contribute to 2% of country's population. In state the landless labourers and small or marginal farmers has only dairy farming as supplementary income [5]. About two third of state population is involved in dairy farming; consequently the livestock population has been increased with 9.57% from 18th livestock census. In Punjab, during livestock census there were 20 districts (Amritsar, Barnala, Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Moga, SAS Mohali, Mukatsar, Mansa, SBS Nagar, Patiala, Ropar, Sangrur, Taran-Taran) which includes urban and rural regions, spread in an area of 50362 square km. In rural Punjab, an age old subsidiary profession for farmers is dairy farming. As per current 19th livestock census, cow and buffalo collectively contributes 93% of total livestock population

in state and also the highest milk producing animals. Animal dung excreted by these animals is a potentially major biomass resource in Punjab and dried form of it has same amount of energy content as wood. The production of dung mainly depends on animal population and dung production per animal. Punjab is the leading state in number of non household enterprise and institutions owing cattle and buffaloes with 67448 and 89127 respectively [6]. With such a large number of diaries or institutions the animal dung will be available at one place and it will be easy to handle for power generation activities in state.

1.2 Energy Conversion Technique

There are many energy conversions techniques, but the most efficient and an appropriate technique for dung conversion to electrical energy is anaerobic digestion [7]. The specific characteristics of animal dung vary with animals and geography but in general dung has high moisture content and volatile solids of total solids and buffering capacity which makes it ideal substrate for anaerobic digestion. Cattle dung in wet form with 80-90% of moisture can be converted into biogas and then to electrical energy by an efficient and appropriate bioconversion process [8]. Anaerobic digestion converts the energy stored in dung into biogas, then later into electrical energy. Anaerobic digestion is the degradation of organic material by microbial movement in the absence of air transforming it into biomass and biogas, a mixture of methane, carbon dioxide and some traces of gases. The anaerobic digester system includes the process of dung collection and handling, pretreatment, anaerobic digestion, biogas recovery, handling and use. In this system the dung is collected and mix with required water. The collected manure may undergo pretreatment like screening, grit removal, mixing and flow equalization. The anaerobic digester is air free sealed container designed to heat or mixes the dung. In anaerobic digester, dung is kept for digestion for 21 days and biogas is formed. Biogas formed in digester bubbles to the surface and collected through a pipe [9-10]. The recovered biogas is combusted in combustion engine to generate electricity. In general biogas consists of 50-75% methane, 25-50% carbon dioxide, hydrogen sulphide and ammonia. The biogas has High Heating Value (HHV) of ranging 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 m^3/ kg [9-10-11-12].

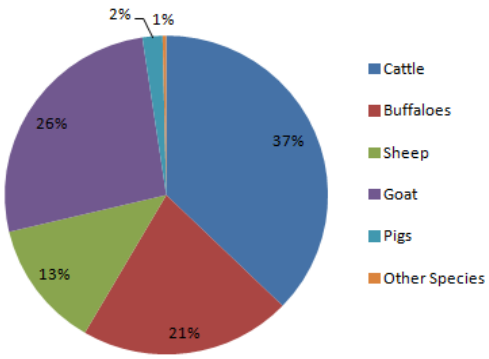

Figure 1. Livestock Population in India

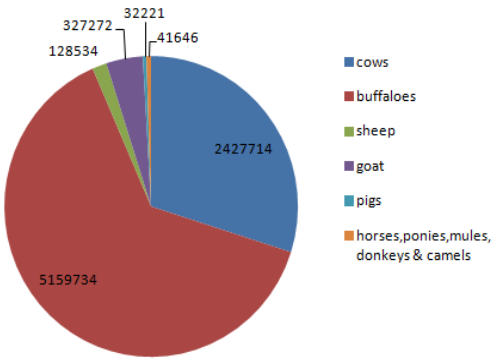

Figure 2. Livestock Population in Punjab

II. MATERIALS AND METHODS

2.1 Livestock Population

The analysis of available livestock population in Punjab state has been done from the latest livestock population census. All types of animals are included in this census, with poultry birds taken separately. For this study the categorization of livestock species is done into five broad categories, the large animals & small animals, pigs, poultry birds and others. The large animals include cattle and buffalo, small animals include sheep and goat, and other animals include horse, camel, elephant, pony, mule and donkey. As per district-wise and species wise total livestock population in Punjab, is 8.1 million, it has 2427714 cows, 5159734 buffaloes, 128534 sheep, 327272 goats, 32221 pigs, 41646 other species with 16794076 poultry birds as shown in figure 2 [13-14] . Table 1 presents the cumulative livestock populations and demonstrates that total large animals, small animals, pigs and poultry population in Punjab is 7587448, 455806, 32221 and 16794016 respectively. The leading three districts in large animal's population are Ferozepur, Ludhiana, Sangrur and in small animals population are Ferozepur, Muktsar and Bathinda. The distribution of this livestock has been evaluated in districts of Punjab on the basis of district wise survey done by Animal Husbandry Department of Punjab. In this study the contribution of other species, being very small is neglected. During census, the state has 20 districts, so population has been taken accordingly.

Table 1. Cumulative Livestock Population of Punjab Districts

Punjab Districts	Large Animals (Cattle & Buffaloes)	Small Animals (Sheep & Goats)	Pigs	Poultry
Amritsar	530970	18336	690	255153
Barnala	233134	11379	752	771765
Bathinda	381472	41625	416	265030
Fatehgarh Sahib	209600	6733	2374	698446
Faridkot	193373	21765	295	136826
Ferozepur	751494	68010	2007	211336
Gurdaspur	543621	20801	934	4354644
Hoshiarpur	408794	18647	532	885097
Jalandhar	387556	19574	1430	441457
Kapurthala	195477	6151	356	204431
Ludhiana	671419	26722	8064	3070679
Mansa	328631	23503	1459	126427
Moga	333577	19016	984	96846
Muktsar	274658	47137	745	283438
Patiala	450801	28464	3241	1324211
Ropar	209184	5686	1290	336804
SAS Mohali	186840	14841	3590	1025930
Sangrur	657876	29828	1696	1989170
SBS Nagar	169840	6752	243	123328
Taran-Taran	469131	20156	1123	193058
Total	**7587448**	**455806**	**32221**	**16794076**

2.2 Assessment of Animal Dung

For the assessment of the total quantity of animal dung production per year from all animal species under study, the available data has been analyzed. It has been estimated that average dung per animal per day is 10-20 kg per day in case of large animals, 2 kg per day for small animals, 4 kg per day for pigs, 0.1 kg per day for poultry birds accounting for 5-6% of body weight per day for large and 4-5% of body weight per day for small, 5-7% of body weight per day for pigs and 3-4% of body weight per day for poultry birds respectively 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. Accordingly, average standard values of 22.5 kg/day (9% body weight,) 1.6 kg/ day (based on 4% of body weight), 2.7 kg/ day (based on 9% of body weight) and 0.045 kg/day (3% of the body weight) were considered for the above mentioned livestock categories [15-16]. The total quantity of animal dung (QAD) in one day is determined from total number of animals (N) and the average dung of per animal per day in kg (D) for number of species of animals (n). The equation (1) represents the QAD.

$$QAD = \sum_{i=1}^{n} N(i) \times D(i) \ldots \qquad (1)$$

2.3 Evaluation of Electrical Energy Generation from Biogas

Electrical energy potential from animal dung can be determined from the biogas potential. Various technologies are available to generate electricity from biogas. The chemical energy of combustible gas methane is converted to mechanical energy in a controlled combustion system by a heat engine. The commonly used heat engines are gas turbines and combustion engines. This mechanical energy then converted to electrical energy and generates power. The production of biogas is affected by animal type, body weight, dung availability and proportion of total solids. The efficient collection of dung is another issue being affected by varied dung availability and wastage of dung during collection. However, uniform means of techniques for collection of the dung need to be standardized in order to meet the requirements for generation of ideal quantities of biogas per unit [15-16-17]. 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 equation (2), (3) and (4):

$$TPB = M^* TS^* AC^* EBTS \ldots \quad (2)$$

$$E_{biogas} = \text{Energy Content}_{biogas} * m_{biogas} \ldots \quad (3)$$

$$e_{biogas} = E_{biogas} * \eta \ldots \quad (4)$$

TPB = Theoretical potential of biogas (m^3 per year)
M = Accumulated quantity of animal dung (QAD) (kg per year)
TS = Ratio of total solids of dung
AC = Availability Coefficient
EBTS = Quantity of estimated biogas (m^3 per kg TS)
Energy $_{biogas}$ = Calorific value of biogas (kWh per m^3)
m_{biogas} = Amount of biogas produced per year (m^3 per year)
e_{biogas} = Quantity of generated electricity (kWh per year)
E biogas = Unconverted raw energy in biogas (kWh per year)
η = Overall efficiency of the conversion of biogas to electricity (%)

In this study, TS value was assumed to be 25% from large and small animal's generated waste. As far as other animal waste is concerned, TS was assumed at 29% for pigs and poultry birds each, with EBTS value calculated as 0.6, 0.4, and 0.8 m^3 per kg TS for large, small, and pigs-poultry respectively. Availability coefficient 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. It is quite evident that methane content of biogas depends upon the type of dung used in the anaerobic digestion. 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 [15-16]. While calculating heating value, heat conversion was calculated as 90% of total harvested methane, which was denoted as heat conversion efficiency in the boiler, assuming that 36 MJ per m^3 of methane is the calorific value. For calculation of potential of electricity generation from biogas, equation (3) was utilized. The η value is considered between 35–42% in large turbine system operated power plants and 25% in small generators. In current study, η value has been assumed as 30%. By using equation (4), 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.

III. DATA REPORTING AND RESULTS

3.1 Animal Dung Production

The results of district wise and species wise quantity of animal dung per day presents that QAD of large animals, small animals, pigs and poultry are 170717580 kg, 729290 kg, 86997 kg and 755733 kg respectively. Assessment present that total quantity of animal dung production per year from all districts and all species of Punjab is 62886 M-kg (million kilograms), 99% of animal dung has been contributed by large animals and only 1% is from small animals, pigs and poultry. These figures are the evident of Punjab residents' large animals' dairy farming occupation and state's agriculture nature. The leading districts in state for animal dung per day production are Ferozepur 6216 M kg, Ludhiana 5588 M kg, and Sangrur 5454 M kg and shown in table 2. Except the above estimated data, the numbers of household owning large and small animals in Punjab districts are Ferozepur (283182), Sangrur (215499), Gurdaspur (210857), Ludhiana (186772), and Amritsar (168560). The leading districts in number of animal farms and diaries for large animals are Jalandhar (473060), Sangrur (18757), Kapurthala (15617), SBSN (11167) and Ferozepur (9211).

3.2 Estimation of Electrical Energy Potential

Animal dung notably has been found as the potential feedstock for sustainable generation of biogas in the anaerobic digestion process. Table 3 reveals the district wise and species wise details of quantity of animal dung per year, TPB per year, methane content per year, heating value per year and total estimated electrical energy generation per year. Results present that total quantity of animal dung production per year from all districts and all species of Punjab is 62886 M-kg. Total TPB, from this accumulated quantity of dung is 6591 Mm^3 (million meter cube) with corresponding methane content of 3954 Mm^3. The amount of heating value is the most considerable parameter for conversion process with significant value of conversion efficiency. The amount of heating value per year from dung is 28896 M-MJ (million-mega joules). Total estimated electrical energy generation per year from all Punjab districts collectively is 11934 M-kWh (million kilo watt-hour) or 11.9 TWh. The leading electrical energy potential districts of state are Ferozepur 1176 M kWh, Ludhiana 1063 M kWh, and Sangrur 1036 M kWh.

Table 2. District-wise, Species-wise Quantity of Animal Dung/Day

Punjab Districts	QAD/ Day (kg) Large Animals	QAD/ Day (kg) Small Animals	QAD/Day(kg) Pigs	QAD/Day(kg) Poultry
Amritsar	11946825	29337.6	1863	11481.89
Barnala	5245515	18206.4	2030.4	34729.43
Bathinda	8583120	66600	1123.2	11926.35
Fatehgarh S	4716000	10772.8	6409.8	31430.07
Faridkot	4350893	34824	796.5	6157.17
Ferozepur	16908615	108816	5418.9	9510.12
Gurdaspur	12231473	33281.6	2521.8	195959
Hoshiarpur	9197864	29835.2	1436.4	39829.37
Jalandhar	8720010	31318.4	3861	19865.57
Kapurthala	4398233	9841.6	961.2	9199.395
Ludhiana	15106927	42755.2	21772.8	138180.6
Mansa	7394198	37604.8	3939.3	5689.215
Moga	7505481	30425.6	2656.8	4358.07
Muktsar	6179805	75419.2	2011.5	12754.71
Patiala	10143023	45542.4	8750.7	59589.5
Ropar	4706640	9097.6	3483	15156.18
SAS Mohali	4203900	23745.6	9693	46166.85
Sangrur	14802210	47724.8	4579.2	89512.65
SBS Nagar	3821400	10803.2	656.1	5549.76
Taran-Taran	10555448	32249.6	3032.1	8687.61
Total	**170717580**	**729289.6**	**86996.7**	**755733.4**

Table 3. District-wise QAD, TPB, Methane Content, Heating Value& Energy

Punjab Districts	QAD/ Year (M kg)	TPB / Year (Mm^3)	Methane Content /Year (Mm^3)	Heating Value /Year (M-MJ)	Electrical Energy / Year (M-kWh)
Amritsar	4376.170232	458.754259	275.220431	8972.186052	830.7579677
Barnala	1934.675647	203.034961	121.801041	3970.713948	367.6586989
Bathinda	3161.910886	330.097275	197.985437	6454.325289	597.622712
Fatehgarh S	1739.083625	182.741909	109.633349	3574.047194	330.9302958
Faridkot	1603.324613	167.355472	100.375151	3272.229926	302.9842525
Ferozepur	6216.811407	649.575540	389.626170	12701.48974	1176.093812
Gurdaspur	4549.080732	479.098551	287.422686	9369.979598	867.5907036
Hoshiarpur	3383.172577	354.822604	212.860893	6939.265109	642.524547
Jalandhar	3202.895062	335.628506	201.342810	6563.775621	607.757002
Kapurthala	1612.655664	169.150344	101.479429	3308.229409	306.3175378
Ludhiana	5588.017161	587.412019	352.400394	11488.54106	1063.727118
Mansa	2716.122248	284.146339	170.446627	5556.560028	514.4962989
Moga	2753.166885	288.226135	172.902365	5636.617102	521.9089909
Muktsar	2288.5465	238.141828	142.802513	4655.361924	431.05203
Patiala	3743.77036	392.536025	235.471745	7676.378931	710.7758269
Ropar	1728.047525	181.395409	108.827284	3547.769462	328.4971723
SAS Mohali	1563.479489	164.125938	98.4495616	3209.455693	297.1718235
Sangrur	5454.569727	572.423707	343.401966	11194.6198	1036.565194
SBS Nagar	1401.019307	146.849325	88.0977659	2871.987169	265.9247378
Taran-Taran	3868.787136	405.368402	243.185728	7927.85474	734.0606241
Total	**62885.7872**	**6591.14124**	**3954.08617**	**128895.6093**	**11934.42813**

IV. CONCLUSIONS

The study concluded that Indian state Punjab has very large potential of livestock dung based biomass as sustainable and renewable energy source. The detailed estimation of quantity and potential of dung has shown that 11.9 TWh per year of electrical energy may be produced through the biogas production. The leading electrical energy potential districts of state are Ferozepur 1176 M kWh, Ludhiana 1063 M kWh, and Sangrur 1036 M kWh. The analysis of data has shown that this is the best way of utilization of dung to meet the ever growing demand of power and dung management.

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