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Prospects of Union Based Biogas Plant Model for the Generation of Electricity in Bangladesh

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Abstract

Biogas is one of the popular forms of renewable energy in Bangladesh. In this paper, the potential of livestock for the generation of biogas has been illustrated. The history of biogas plants, related activities and electricity generation from biogas in Bangladesh has also been discussed. Based on the potential, the union based biogas plant model has been presented and described how it would work. Three different divisions of Bangladesh have been considered for evaluating the potential and viability of this model. Under this model, each union can contribute 0.09 MW of electricity, and in total 161 MW of electricity can be generated in those divisions. This model can be handy for rural development but will be very challenging to implement and several factors required to be checked before the installations.

Keywords: energy, history, biogas, unions, livestock, conversion, challenges

Introduction

Bangladesh, technically one of the significant countries in the south Asian territory, has been emerging rapidly for the last few decades, and hence the energy crisis is one of the biggest obstacles to the progress. About 70% of the total population of Bangladesh inhabits rural areas. According to the government's estimation, 58% of total households are under the grid connection and with the contribution from renewable energy, about 70% of the population has access to electricity. The government is planning to link 98% of the households mainly through the grid extension within 2021[1]. In recent years there is an advancement in the power generation, and the capacity of the generation which includes the captive power and renewable energy has reached 20,000 MW. The present peak power demand in Bangladesh is more than 12000 MW, and the regular generation is over 8000 MW [2], and the highest generation was 11,387 MW [3]. Besides, the work of establishing the first-ever nuclear power plant has been going on. It has been anticipated that the demand will be over 33000 MW by 2030 [4]. The power plants run on several fossil fuels, and most of them are natural gas based, which will eventually finish within a few decades [4]. Besides, only less than 10% of the total population has access to the gas supply for cooking. So, they have to employ other fuels like kerosene or wood.

To solve or minimise energy problems, renewable energy is quite promising. There have been many efforts led by the Bangladesh government and private organisations. According to the Sustainable and Renewable Energy Development Authority (SREDA) renewable energy has the potential to contribute 534 MW of electricity, which is 2.84% of the total generation [5]. Among the renewable energy activities, solar energy is the most prominent in Bangladesh, contributing about 300 MW of electricity. Several solar parks are under planning which will provide 100 MW each. Hydropower is next to solar energy, contributing 230 MW of electricity [5]. There is some potential for wind energy in the coastal regions in Bangladesh, and the plants established in Kutubdia and Feni are producing 2.30 MW of electricity [6].

Biogas is considered a promising technology for Bangladesh [7]. The production temperature of biogas through the anaerobic digestion is also favourable in Bangladesh. In rural areas, many of the households are using domestic biogas plants for cooking. Biogas plants also yield high-quality fertiliser. But the generation of electricity through biogas is still deficient in Bangladesh, contributing only 0.68 MW of electricity [5]. The number of the Biogas-Electricity plant is also very low compared with the total number of plants.

To increase the electricity generation from the biogas plant, we have proposed a model. Before going to that, let's see the potential of livestock in Bangladesh first. We will discuss the situation of biogas plants and generation of electricity from biogas plants. After that, based on our collected data, we will talk about our proposed union based biogas plant model with its capacity for electricity generation, viability, and challenges.

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Livestock Potential In Bangladesh

Livestock has been an integral component of the complex farming system in Bangladesh. It serves both as a source of meat protein and farm power services. In the past few decades, it's also been a way to self-employment. This specific sector provides full-time employment for 20% of the total population and part-time employment for another 50% of the total population [8]. Livestock products, mostly leather and leather products, are also contributing to the country's economy. Though the grazing facilities are limited and decreasing rapidly, still the livestock production has been showing the upward trend (in Figure 1).

Biogas Plants In Bangladesh

In Bangladesh, the first-ever biogas plant following 'Indian KVIC floating-drum model' was installed in Bangladesh Agricultural University campus, back in 1972. The capacity of biogas production of that plant was 3cm^3, and it was introduced for research purpose. Initially, the construction cost was high, and no subsidy was available from the government; that's why the number of constructed plants was limited. With the help of IFRD, 72 such biogas plants were built at various locations of the country from 1972 to 1980. The number of biogas plants began to accelerate in the '80s. Several government administrations like

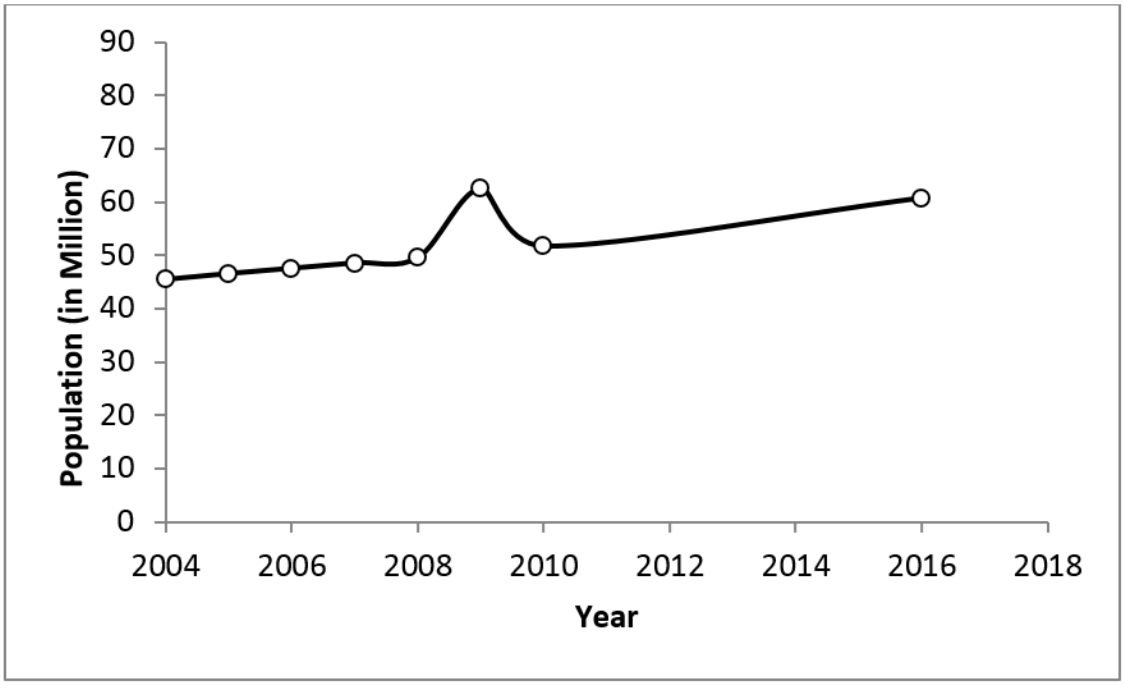

Figure 1 Livestock Population of Bangladesh [9, 10, 7]

According to the Ministry of Fisheries and Livestock (2011), Bangladesh Bureau of Statistics (BBS), (2011) and Food and Agriculture Organization Statistical Databases (FAOSTAT), there are more than 60 million domestic animals including cows, buffaloes, goat, and sheep in Bangladesh. According to FAOSTAT (2016), there are 23.8 million cattle and 1.5 million buffaloes in Bangladesh, and the number is increasing every year. The average dung production of each cow or buffalo is approximately 10-11.5kg per day [11, 12]. According to The Institute of Fuel Research & Development (IFRD) under the proper condition, the amount of gas produced by each Kg of dung is approximately 1.3 cubic feet [13].

Environment Pollution Control Department (EPCD), Bangladesh Council of Scientific and Industrial Research (BCSIR), Department of Livestock (DLS), Local Government Engineering Department (LGED) took several projects and constructed more than 450 small sized biogas plants across the country. Some Non-Government Organizations like Building Resource across Communities (BRAC), Grameen Bank, and Danish International Development Agency (DANIDA) with the technical support from BCSIR built several biogas plants. They have also introduced the trench and plastic bag type digesters in Bangladesh [14, 15].

During 1992 -1994, several other pilot schemes were undertaken by LGED employing different forms of constituents like city wastes,

human excreta, water hyacinth, and poultry droppings etc. In the meantime, they were also providing the training program to the youth to train them about the construction and maintenance of the biogas plants [16]. At that time, the government also initiated providing the subsidy. In 1995, BCSIR took "Biogas Pilot Plant Project". From 1995 to 2004 they built more than 21,000 fixed dome biogas plants all over the country. At the same time (1998-2003) LGED also fabricated about 1,100 domestic plants. From 2006 to June 2018, Infrastructure Development Company Limited (IDCOL) with support from World Bank, Kreditanstalt für Wiederaufbau (KFW, German name, means "Reconstruction Credit Institute") development Bank and Netherland Development Cooperation (SNV) have installed more than 48000 biogas plants in different zones of Bangladesh [14]. The plants are designed for two types of raw ingredients – one is for cattle dung and human excreta and the other one for poultry droppings.

There are six different capacities of plants for each design. The daily gas production capacities of these plants are ranged between 1.2 m^3 to 25.0 m^3 which meet the demand of both domestic households and mid-sized dairy or poultry farms. IDCOL currently finances two models of plants (brick-cement based plants and fibreglass bio-digester based plants). National Domestic Biogas and Manure Program (NDBMP) is presently the most extensive biogas program of the country instigated by IDCOL [17]. Grameen Shakti is a significant organisation that has been working with IDCOL, and they have also made many biogas plants for domestic usages under their EcoVillage Development Project.

Moreover, German Technical Cooperation (GTZ), under the program 'Sustainable Energy Development', has created an opportunity to support installation and financing of large biogas plants with a capacity of above 4.8 m^3, established mostly in commercial poultry, dairies, and slaughterhouses [13]. According to GTZ, about 440 plants have so far been constructed. Besides, under the 'Youth Development through Employment and Income Generation Program', Ministry of Youth and Sports has an ongoing biogas program in ten selected areas of Bangladesh. According to the Sustainable and Renewable Energy Development Authority (SREDA), some 73,152 biogas plants are currently run in Bangladeshi villages, and the Fixed Dome biogas plants are persistent [18]. The regular investment cost of a biogas plant in Bangladesh is about USD 400 while for Pakistan, Nepal, Vietnam, China, Rwanda, Tanzania, and Kenya were estimated to be 426, 547,480, 293, 1306, 780 and 787 USD, respectively [4].

Biogas Plant And Electricity

Biogas possesses chemical energy, which can result in electricity after the conversion of chemical energy to mechanical energy by utilising the transducers like generators and turbines that convert energy from one form to another. This electricity can be used both for domestic and commercial purposes, and it can be made in small and large scales. In most cases, biogas is used as fuel for combustion engines, which convert it into mechanical energy, powering an electric generator to produce electricity. Appropriate electric generators are available in virtually all countries, in all sizes and the maintenance is simple [19].

Currently, countries like China and India are the pioneers in electricity generation from Biogas plants. In Europe, there have been many innovations applied to increase electricity generation from biogas. In Bangladesh, electricity generation from biogas started after 2000. IDCOL is the leading organisation in installing these plants, and up to 2016, they have installed 7 such plants that are capable of producing 0.69 MW of electricity [5] which is only 0.1% of the total electricity that comes from the renewable energy sources. The biggest one of them is situated in Gazipur, which has the capacity of producing 0.40 MW of electricity. Bangladesh Power Development Board is planning to install a one MW grid-connected biogas plant near Dhaka within 2020. Besides these, many domestic biogas plants around the country are making electricity from biogas.

Union Based Biogas Plant

Community-based biogas plants have been common in many parts of the world. Countries like China and India have a large biogas plant for the generation of electricity, and it has been proved economically fruitful over the years. The community-based biogas plant has also been used in other Asian countries like Nepal, Myanmar, and Thailand etc. In Europe, countries like Denmark, Finland, Netherlands and Poland are also utilising this technique.

There are more than 86 thousand villages in Bangladesh. In Bangladesh, Union councils or usually known as Unions are the smallest rural administrative and local government units. It is made up of nine Wards. Here one village is designated as a ward. Currently, there are 4,554 unions in Bangladesh. A Union Council consists of a chairperson and twelve members including three members exclusively reserved for women. The average area of a union is 20 square kilometres, and about 25 thousand people live in a union on an average [20].

We are proposing a amalgamation based biogas plant for the generation of electricity. It will work quite similar to the community-based biogas plants, but it will cover a greater area for the greater amount of electricity generation. We can use all sorts of wastes for the biogas production, but for our calculation, we are considering only the cow and buffalo dung for the biogas generation. We will consider unions with a specific amount of cows/buffaloes with a minimum amount of manure to collect. The muck will be obtained from the owners of the animals that will be carried by vehicles. Then

it will be accumulated in the traditional way to produce the biogas and from that generators will produce electricity and supply it to the transmission line. Figure 2 is illustrating the union based biogas plant.

Currently, there are 8 divisions in Bangladesh. In order to understand the viability and the potential of this type of biogas plant we have selected three divisions of Bangladesh (Dhaka, Chittagong and Khulna) and the shaded regions are indicating

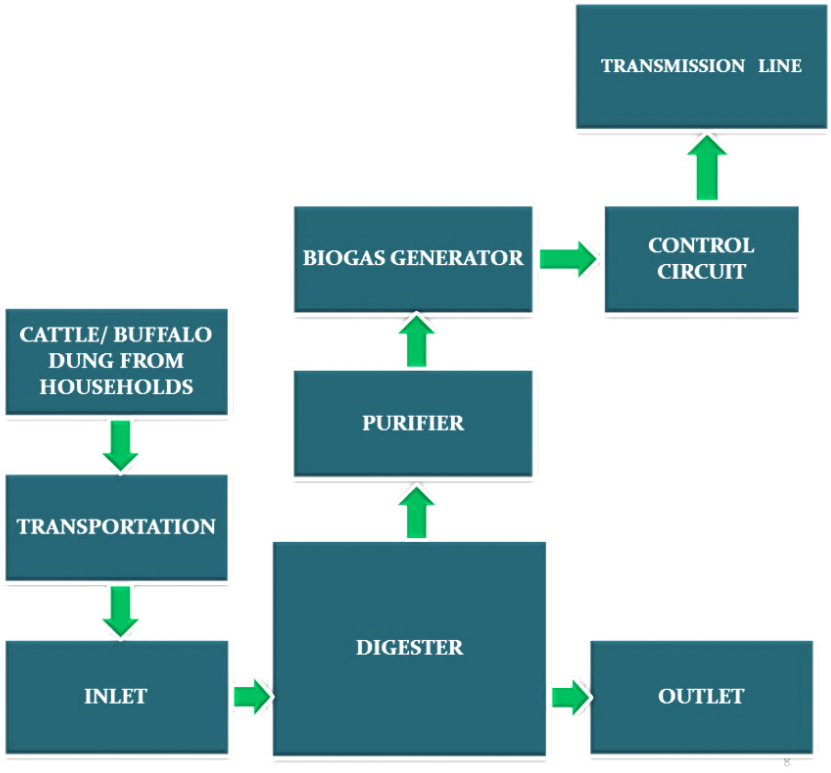

Figure 2 Block diagram of a union based biogas plant

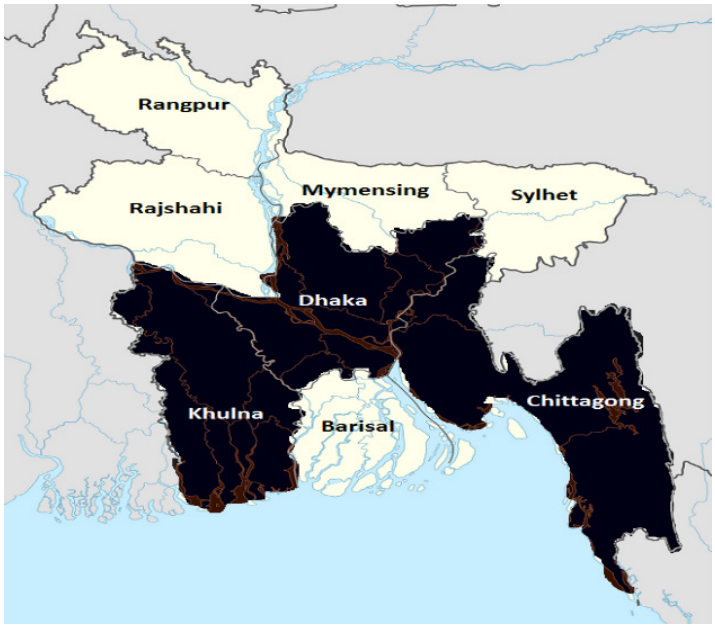

Figure 3 Map of Bangladesh (The shaded regions on this map are the areas under study)

the areas (Figure 3). We have collected the data about the number of unions, cow/buffalo population of those divisions (Table 1, 2, 3) from BBS Figure [21]. The normal distributions of the tables with relevant statistical information are also given in Figure 4, 5 and 6.

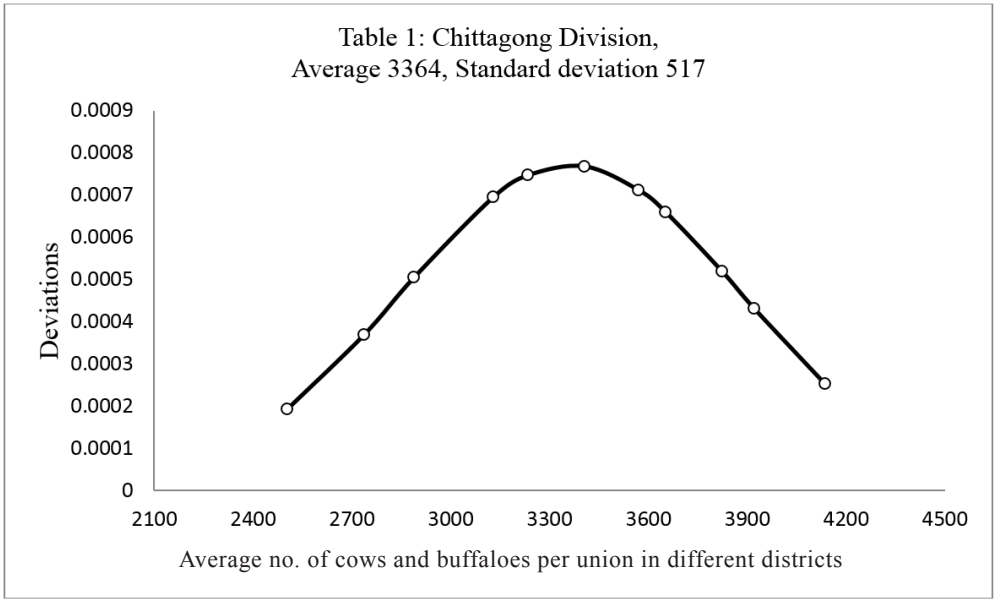

Figure 4 Normal distribution for Table 1 (Chittagong).

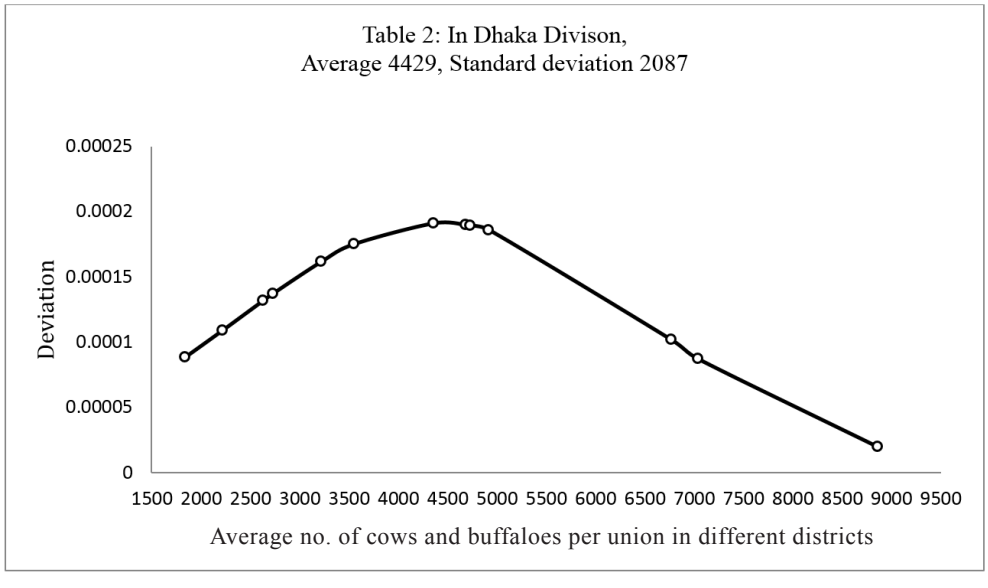

Figure 5 Normal distribution for Table 2 (Dhaka)

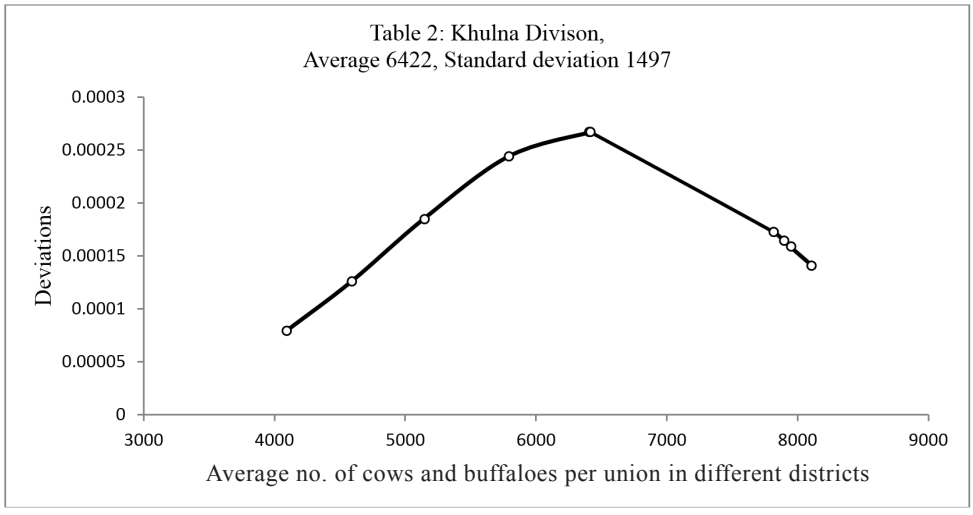

Figure 6 Normal distribution for Table 3 (Khulna)

Table 1 Data for Chittagong Division

District Name	No. of Upazila	No. of Union	Total number of cows/buffalo	Cows/Buffalos per Union (Average)
Brahmanbaria	9	98	268220	2736
Bandarban	7	30	97076	3235
Chandpur	8	86	307171	3571
Chittagong	15	206	595181	2889
Comilla	16	169	662900	3922
Cox's Bazar	8	71	259348	3652
Feni	6	43	134604	3130
Khagrachori	8	37	141504	3824
Laxmipur	5	53	180561	3406
Noakhali	9	91	376394	4136
Rangamati	10	49	122758	2505

Table 2 Data for Dhaka Division

Name Of District	Upazila	No. of Union	Total number of cows/buffalo	Cows/Buffalos per Union (Average)
Dhaka	6	55	260119	4729
Foridpur	9	79	388681	4920
Gazipur	5	43	381067	8862
Gopalganj	5	67	238396	3558
Kishorganj	13	107	501650	4688
Madaripur	4	69	188345	2729
Manikganj	7	65	209498	3223
Munshiganj	6	67	123407	1841
Narayanganj	5	42	93164	2218
Narsingdi	6	70	305492	4364
Rajbari	5	42	284314	6769
Shariatpur	6	65	171025	2631
Tangail	12	108	760885	7045

Table 3 Data for Khulna Division

Name Of District	Upazila	No. of Union	Total number of cows/buffalo	Cows/Buffalos per Union (Average)
Khulna	10	75	343998	4586
Bagerhat	9	76	310936	4091
Sathkhira	7	78	451593	5789
Jessore	8	92	719410	7819
Jhinaidah	6	67	532707	7950
Chuadanga	4	32	259504	8109
Magura	4	36	230776	6410
Narail	3	38	195583	5146
Kushtia	6	66	423801	6421
Meherpur	3	18	142198	7899

Table 4 Required parameters for the calculation of electricity generation from the plant for one Union

No. of cows and buffaloes under consideration	2500
The expected amount of dung to be collected per cow or buffalo	6 kg
The total amount of dung	15000 kg or 15 Tons.
The maximum amount of gas that can be produced under proper condition (M_{BIO}) (1 kg of Dung = 1.3 Cubic feet)[1	19500 cubic feet or 552m^3
Considering Methane fraction (M_F)*	50%
Lower Heating Value of biogas (L_{HV}) [19]	14 KJ/kg
The density of methane (ρ)	0.656 kg/m^3
Considering the efficiency of the gas engine/ Generator (Π)*	30%

Here '*' is denoting the considered values.

Table 5 Overall electricity generation

Electricity generation from one union	88.21 kW or 0.09 MW
Electricity generation from Chittagong division	52.2 MW
Electricity generation from Dhaka division	57.24 MW
Electricity generation from Khulna division	52.02 MW
Total	**161.15 MW**

Results

The data (Table 1-3 and Figure 4-6) shows us that the unions of these divisions have at least 2000 cows and buffalos and about 47% of those unions have 3000 to 5000 cows. In general, 80% of the unions have more than 3000 cows (Figure 7). For collecting the main ingredients for the plants here we have considered 2500 cows and buffaloes, and then the unions should or expected to have more than three thousand cows and buffaloes. 2390 unions fulfil the criteria under the study area. The data is given below in Table 6.

The electrical energy from biogas can be calculated [22] by the following equation,

Electrical energy = $M_{BIO} \times M_F \times L_{HV} \times \rho \times \eta \times 1.16 \times 10^{-5}$ ———(i)

Where

M_{BIO} = Maximum amount of gas that can be produced under proper condition,
= Total amount of ingredient (in Kilograms)×biogas production per kilogram

M_F = Methane fraction,

L_{HV} = Lower Heating Value of biogas,

ρ = Density of Methane,

η = Efficiency of gas engine/ Generator

Table 6 Total number of unions that have a population (cows & buffaloes) greater than 3000

Chittagong	580
Dhaka	636
Khulna	578
Total	**1794**

All the considered values for our proposed model are given in Table 5 and using equation (i) we have found that at least 0.09 MW of electricity can be produced per union and more than 50 MW of electricity can be produced from each of the divisions that we have studied (Table 6).

or diesel used for lighting or other purposes. Apart from the electricity generation, biogas plan also provides high-quality fertilisers, which can be very useful for agriculture. If the fertilisers can be appropriately distributed, it will help the farmers. This type of biogas plant will also reduce pollution at a smaller scale and will

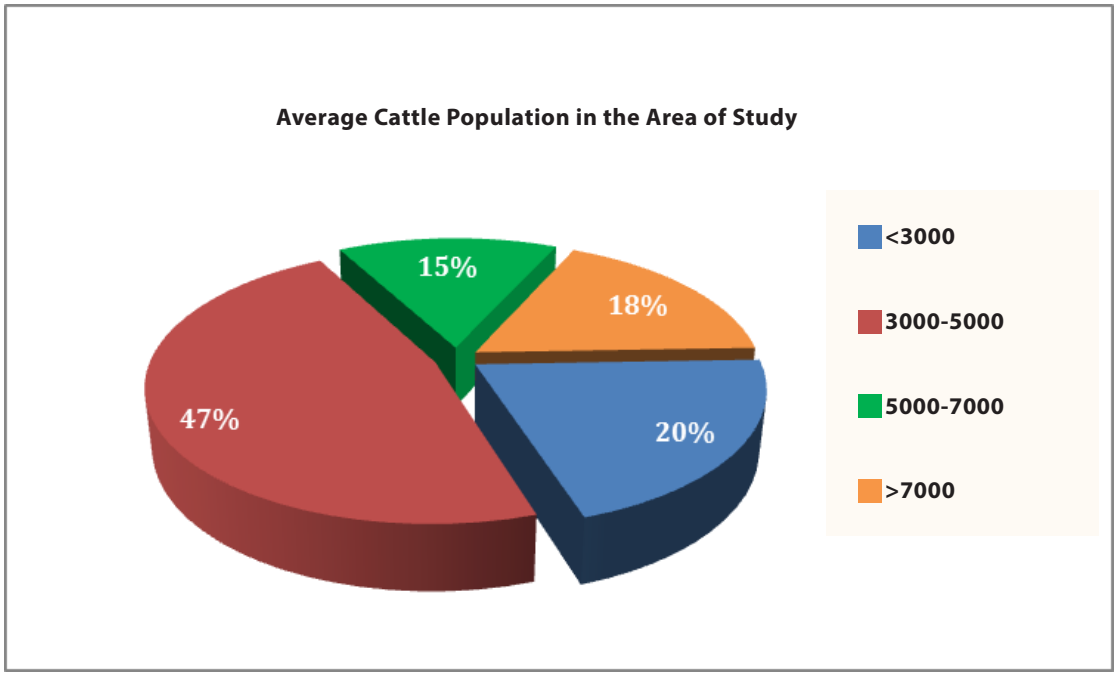

Figure 7 Normal distribution for Table 3 (Khulna)

Benefits and Challenges

In our study, we have considered only three divisions. The quantity could have been much higher if we had studied all the divisions, but still, the quantity is about one-third of the current entire electricity generation from renewable resources and only behind the contributions from solar energy [5].

By implementing this type of Biogas plants, the remote places where electricity transmission is difficult or hasn't reached yet can be highly benefitted. Many people will enjoy the benefits of electricity. It will reduce the utilisation of fuels like kerosene

constitute a healthier environment. The construction process and the maintenance of those biogas plants will ensure employment for many people and will help to improve the economic condition to some degree.

The produced electricity can also be diverted or supplied only to the industries or factories near the plants at a reasonable price, and the money can be distributed among the farmers who will contribute raw materials for the plants which will also inspire them for further enhancement of their farms or livestock production. The government can also earn some revenue from that.

However, the construction of this type of biogas plants will not be easy. The dimension of the biogas digester and the transportation of raw material can be challenging. With some other components like the generators or controlling circuits, the installation cost will be huge. Before the installation, several surveys are required to ensure economic feasibility or viability. The help of the citizens of the unions is also essential. Without their assistance, it will be much more difficult. There are issues with the temperature too.

During winter, the temperature in the northwestern region of Bangladesh and some part of the north-eastern region goes below 17°C which is not ideal for anaerobic digestion in the biogas plant and the production will not be the same as expected so before installation the temperature factor required to be examined. Biogas plants need water, and that's why these plants should be installed with the proper water supply, which can be difficult in some places to ensure. As Bangladesh is often visited by natural hazards [21] like cyclones, earthquakes, floods, the plants should be planted in those locations with the proper protection to maintain continuous production. For proper maintenance, trained workforce is also a challenge.

Future Research Scopes

In this union based biogas plant model, we have proposed cow and buffalo dung only as raw material, but we know that some other ingredients or wastes can be utilised for biogas production especially poultry wastes are excellent for biogas production. Employing miscellaneous wastes in the biogas plants in a larger quantity will increase the production. This will also reduce the wastes and waste management cost and ultimately will ensure a healthier environment. Studies can be done for the transportation system and the amount of money required for the installation of this type of large plants which are absent in this paper. Studies can also be done for the transmission system of the generated electricity, and different innovative ways can be proposed for making this model more efficient.

Besides, in this paper, we are only dealing with the generation of electricity, but biogas is more traditionally used in cooking. So with this existing model, we can also calculate how many households can be benefitted from the biogas generated in a plant in a specific union.

Conclusion

After the analysis of the collected data, we have seen the potential of our proposed union based biogas plants. Besides, the installation of these plants can introduce job opportunities for many people and will also help in making a healthier environment. We have considered the average number of cow/buffaloes for our study, and so the actual figure can deviate from our estimation in some cases. We have reviewed a specific amount of dung, and the number of cow/buffaloes was also accurate. Taking into account the population of cows and buffaloes we can see that, on an average many of the unions have greater than 5000 cows/buffaloes which indicate the possibility of getting a higher amount of raw materials for biogas production. Also, we have considered only 50% of the methane from the produced gas and 30% percent engine efficiency; both of them can also vary.

However, the suitable location, temperature variation, entire cost etc. are the obstacles to the installation of these plants. But if the initiatives are taken properly, it will, highly benefit the rural people and will accelerate the development process in Bangladesh.

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