



## Evaluation of Biogas as an Alternative Driving Force of Electrically Operated Vehicles: A Case Study

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### ABSTRACT

In the present world, energy is indispensable for maintaining the comfort level and living standard of the human. On the other hand, the energy crisis is a major problem in most of the developing countries like Bangladesh. A possible reason is that, the decreasing level of conventional energy sources and the lack of initiatives for introducing the alternative sources of energy. Moreover, the inefficient and illegal way of using energy contributes to the energy crisis. In this study, the present scenario of the electricity generation and its usage in Bangladesh has been investigated. It appears that the increasing amount of battery operated vehicles and their demand for electricity is one of the main reason for energy deficit in the country. The biogas technology as a potential renewable source of energy could be proved as an efficient solution to the energy crisis. For the further studies, a feasibility study is carried out showing that the biogas technology is economically feasible for producing electricity. Moreover, environmental effects, social benefits, and challenges for setting up a biogas plant have been evaluated.

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### 1. INTRODUCTION

In present world one of the most brain storming concepts is energy. The demand for energy has been increasing at a great speed all over the globe along with the increasing rate of the population [1]. At present, the energy consumption rate is doubled from 1980 and expected to be five times in 2100 [2]. Moreover, the world is gradually reaching the end of its reserve of conventional energy [3, 4]. Apart from that, the way of using the conventional energy sources and its contribution to the environment pollution make the present power producing systems unsustainable [5]. Figure 1 shows the Green House Gas (GHG) emissions from different sectors globally running on the conventional sources of energy. Among the different sources, the maximum GHG emitted from the electricity and heat sectors. As a result, the need for introducing alternative sources or the renewable energy sources has been promoted [6]. In recent times, almost all of the

developing countries like Bangladesh are suffering from energy crisis [7]. Realizing the importance, developing countries are investing huge budget for the renewable energy technologies.

Bangladesh is one of the most densely populated countries in the world. Its 35.6% population lives in the urban and the rest population which is 64.4% lives in the rural area [6]. Its population growth rate is 1.18% [8]. Bangladesh has a very promising GDP growth rate of 6.8% slightly less than the previous year growth rate which was 7.1% [9].

Power generation in Bangladesh is almost fuel dependent i.e. existing power plants are mostly operated on natural gas (about 62%) followed by fossil fuel, coal, and diesel [6]. Figure 2 illustrates the production of electricity both in public and private sectors, respectively. The government has undertaken so many initiatives for increasing the yearly electricity production. Although the electricity generation rate is increasing in every year from 2013 to 2017 but not enough to cope with the demand.

Bangladesh uses and consumes proportionately more fossil fuel than neighboring countries [10].

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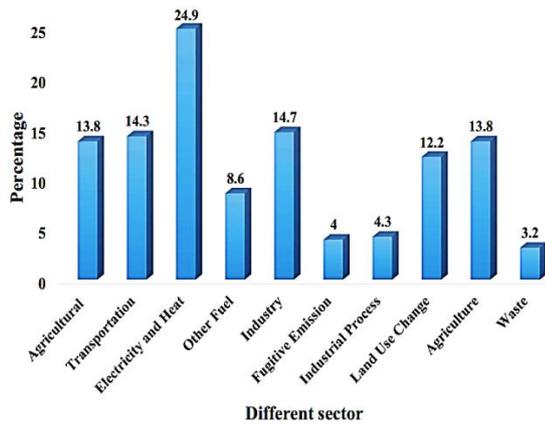


Figure 1. GHG emissions globally in different sectors [11]

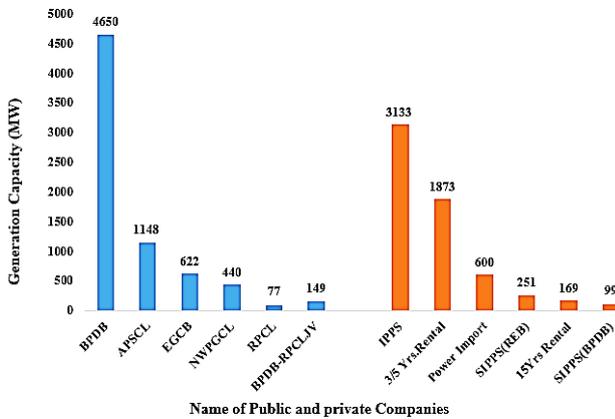


Figure 2. Electricity generation by public sectors and private sectors in Bangladesh in 2017 [12]

Transportation sector and Power generation sector are the largest consumer of fossil fuel [13]. In the transport sector, the battery operated vehicle is increasing rapidly such as auto-rickshaw. But the process of charging the battery causes a huge amount of electricity consumption which leads the country towards the severe load shedding problem [14].

As Bangladesh is mainly an agricultural country and its GDP's 20% contribution comes from agricultural and forestry sector [15]. Biogas has the potential to produce heat, gas, and electricity. Figure 3 ensures that about 20% of global electricity is generated using biogas. Bangladesh government has also taken a vision of producing electricity 10% by 2020 and 100% by 2050 using renewable sources [16]. Biogas technology has an important role to play to update life standard by solving this problem [17].

Several research works have been done in the field of biogas and its application throughout the world [18, 19]. Iqbal et al. [20] investigate the prospect, potential, and barriers of biogas technology in Bangladesh details.

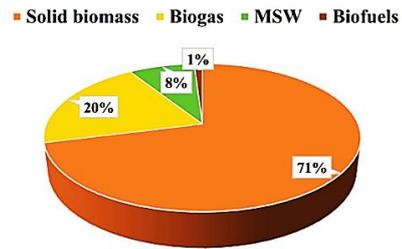


Figure 3. Biomass resources in global electricity generation in 2015 [21]

Huda et al. [22] not only focused on the technological use of biomass but also discussed the project undertaken by the government and non-government organization and their achievement to promote the biogas technology in Bangladesh. Kabir et al. [23] discussed the factors affecting the biogas plant technologies in Bangladesh.

Cuellar et al. [24] suggested that the GHG emissions from the manure directly can be reduced significantly using the biogas technology. More Studies have also been carried out to establish that the renewable source of energy is more feasible and appropriate for Bangladesh in a sustainable way [25]. But no researchers suggests that biogas could be the solution for the newly formed problem i.e battery operated vehicles power supply problem and effects on national grid electricity supply.

The objective of the study is to carry out the feasibility study and analyze the environmental impact of the selected area. In addition, a design calculation for a biogas plant is proposed along with the pros and cons. Finally, social perspectives are analyzed by the door to door visiting of the selected research area which is not reported on many of the above research works.

## 2. CURRENT STATUS OF BIOGAS TECHNOLOGY IN BANGLADESH

### 2.1. Present Livestock Scenario in Bangladesh

Being an agricultural country, people in Bangladesh nurture mainly cattle, chicken, buffalo, for satisfying their agricultural need. Some people use them for their daily needs and some utilize them for financial income. An updated statistics of livestock has been shown in Table 1.

### 2.2. Environmental Stability

The optimum temperature for setting up a biogas plant in Bangladesh is 6°C-40°C which falls in the range at which the anaerobic digestion occurs. Biogas also reduces the GHG emissions in comparison with conventional fuels [26].

**TABLE 1.** Livestock population in Bangladesh in (2015-2016) [27].

Livestock species	Number (2015-2016) in million
Cow	23.785
Buffalo	1.471
Chicken	268.393

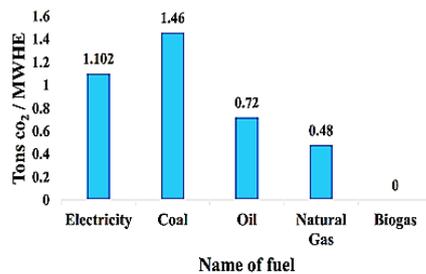
From the Figure 4, it is clear that the emission of GHG is most in the case of coal followed by the electricity and oil where biogas emits no GHG.

**2.3. Production of Biogas with Plant Size** The size of the plant depends on the number of feeding materials that have to be employed in the digester. Due to the availability, quality, and quantity, the cow dung is considered as a feeding material in this study. Different types of cow produce the various amount of cow dung. Table 2 shows details information about plant size and dung amount with the number of cattle required. On average Bangladeshi cow produces 10-15 kg dung per day [28].

### 3. CONVERSION OF ELECTRICITY FROM BIOGAS

#### 3. 1. Battery Operated Vehicles in Bangladesh

The number of battery operated vehicles in Bangladesh is rapidly increasing because of its environment-friendly and comfortable nature.

**Figure 4.** GHG production by fossil fuel [26]**TABLE 2.** Biogas plant design details including size, dung amount, animal number [28]

Size of plants (gas production/day) (m <sup>3</sup> )	Amount of Wet Dung Required (kg)	No. of animals
2	35-40	2-3
3	45-50	3-4
4	55-60	4-6
6	80-100	6-10
8	120-150	12-15
10	160-200	16-20

Moreover, battery operated vehicles are less speedy which leads to less accident [29]. But it may cause a threat to the country because of its huge amount of energy consumption beyond. The total number of registered battery operated vehicles in Bangladesh are 232303 (up to June 30, 2016) [29]. The rated power consumption by the battery operated vehicles is 8.4kWh. But by direct observation, the actual power consumption is 10kWh which depends on the age of the battery. As the battery is used regularly it requires more power to get charged fully. Since the transmission loss is 16% of actual power so total power consumed by auto-rickshaw is 11.6kWh [30]. The total power consumed by the authorized auto-rickshaw is 2694.71kWh.

**3.2. Conversion of Biogas into Electricity** A brief calculation of electricity production from the biogas has been discussed in this section along with the electricity required for the charging of the battery-driven vehicles. The calculation of electricity generation is done by considering the mostly available feeding material cow dung as shown in Table 3.

Consider that, each cow produces at least 10 kg of dung per day and maximum gas production per kg of cattle dung is 0.037 m<sup>3</sup>. Biogas generator efficiency is considered as 40%. The amount of electricity that can be produced from cow manure is 18578727.78 units. After charging all the auto-rickshaw with the electricity produced from cow manure the remaining electricity is 18576033.07 units.

From the above calculation, it is certain that a huge amount of electricity can be saved even after the charging of those vehicles. In addition, as a by-product, organic fertilizer can be obtained called bio-slurry [31]. Figure 5 represents the percentage of nutrients in cow manure before and after digestion [32].

### 4. FEASIBILITY STUDY

**4. 1. Economic Benefits** The people of Bangladesh uses electricity as a main form of energy for satisfying their needs. Although biogas is the probable solution to save the economy; nonetheless installation cost of the biogas plant is the main parameter to be considered during the economic analysis.

**TABLE 3.** Details equations for electricity generation from biogas

Factors	Equation
Total gas	(Total feeding material in kg × maximum gas production per kg of feeding materials)
The available electric energy	(Total gas in kWh × biogas generator efficiency)

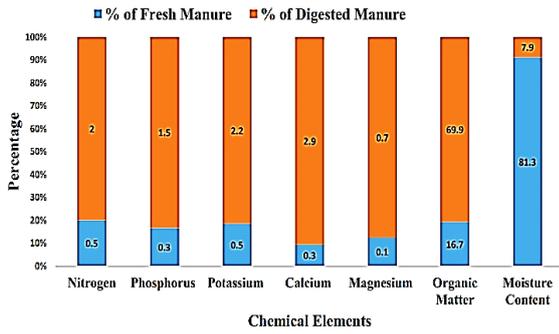


Figure 5. Nutrients and Chemical elements in cow manure

Apart from that, it also depends on the break-even point, net present value (NPV), and internal rate of return (IRR). For the risk-free investment and short time recovered a higher HPV and IRR is required [33]. Following equation are used for calculating those parameters [33].

$$\text{Payback Period} = \frac{I}{R - E} \tag{1}$$

$$NPV = \sum_1^n \frac{(B_n - C_n)}{(1+r)^n} \tag{2}$$

$$IRR = (r_1 - NPV_1) \frac{(r_2 - r_1)}{(NPV_2 - NPV_1)} \tag{3}$$

Here,  $I$  represents the investment,  $R$  is the revenue,  $E$  indicates the expense,  $B_n$  is the total benefit,  $C_n$  is the total cost,  $r$  is the discount rate,  $NPV_1$  and  $NPV_2$  are for two different interest rate and  $n$  is the biogas plant lifetime which is normally considered 20 years.

The economic benefits include the benefits of the biogas and the bio-slurry. In this study, the financial acceptance is evaluated based on benefits, electricity production, cost analysis and time required and cost saved of a proposed biogas plant in a selected area. Such an area Kumarpara Ghoshpara has been selected for the proposed biogas plant which is situated in the Rajshahi district, Bangladesh. The reason for selecting that area is that the percentage of a cow in this area per family is more than any other area in Rajshahi city corporation. Here, most of the male family members live on by driving battery-driven vehicles. Moreover, families support themselves by selling milk and other foods prepared by the milk. So, this area is quite ideal and suitable for setting up the biogas plant. Table 4 shows the number of cows and family member of the area that has been selected. This data is collected by a survey of fifteen families in that selected area. In total fifteen families have the 53 cows.

TABLE 4. Family members and cows number of the selected area

Serial no	No. of family members	No. of cows
1	8	2
2	3	8
3	7	1
4	5	4
5	3	4
6	7	4
7	3	2
8	5	2
9	10	4
10	11	3
11	5	1
12	15	6
13	4	6
14	6	4
15	5	2

**4.1.1. Electricity Production** Based on Tables 2 and 4 a plant is designed of size 20-22 m<sup>3</sup> approximately. It is assumed that each cow produces 10kg of dung each day. Here, the maximum gas production per kg of cow dung is considered as 0.037 m<sup>3</sup> and the biogas generator efficiency is taken as 40%. So, the available electricity obtained from the biogas plant is approximately 41.39 unit.

**4.1.2. Break-Even Point** Break-even point is a point where the total cost and total revenue is same. The cost mainly includes installation cost, maintenance or replacement cost. The cost of equipment and all the accessories such as bricks, cement, labor, technician, and all other things varies from place to place. For the calculation, the value of cost is considered by surveying different local biogas development society or organization. For the simplicity of the calculation, all factors have not taken into consideration.

In setting up all the equipment and complete the total biogas plant setup process, the cost is considered BDT 200000 including the maintenance cost (based on field survey data). The unit electricity cost in Bangladesh is BDT 8.00 and operating time is considered 24 hours. In local market of Bangladesh, the price of per 50 kg bio-slurry bag is BDT 300. According to the survey results, almost 70 - 80% of feeding materials into the biogas plant is normally collected as bio-slurry.

By evaluating the factors from Table 5, the break-even point is found 6 months or in another word, the proposed biogas plant will be profitable after 6 months.

**4.1.3. Time and Cost Saved by Charging The Battery**

As per the local survey data, an auto-rickshaw battery takes about 11-12 hours to fully charge and it costs about BDT 150-200 for charging only one time. The local charging stations have to pay near about BDT 10-13 per unit [34]. Even sometimes auto-rickshaw drivers have to wait in queue for charging which has a negative impact on their working hours, especially on income rate. In the case of biogas plant, it is advantageous in every possible way than the normal grid connection in terms of charging the battery.

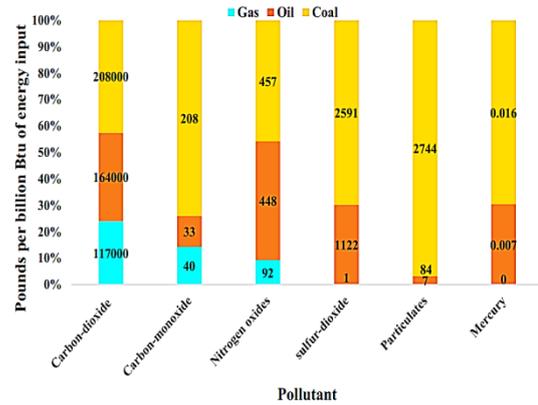
**4.2. Environmental Aspects** Biogas can play the role of the light bearer in a developing country like Bangladesh against problems like global warming, natural calamities. These conventional fuels have a negative impact on the environment. This can leads the country towards the deforestation and different types of natural calamities as well. Figure 6 shows the emission of pollutants from a natural gas, oil, coal operated sectors.

Biogas contributes less than the conventional sources of the environmental pollution as it contains 50 - 70% methane and little amounts of  $CO_2$ ,  $H_2$ ,  $N_2$ ,  $O_2$ ,  $H_2O$ ,  $NH_3$  [35]. Moreover, Bio-slurry could boost the agricultural system of Bangladesh as an organic fertilizer instead of traditional fertilizer.

**4.3. Social Benefits** Electricity consumption is an important factor in terms of evaluating the life standard of people [36]. It also helps to develop the quality of society in an overall way. The people living in the proposed area live on working on a daily basis.

**TABLE 5.** Details equations for calculating the break-even point

Factors	Equation
Income from selling electricity in BDT per month	(electricity obtained from biogas plant $\times$ operating time $\times$ unit electricity cost)
Total Manure	(total number of cows $\times$ manure produce per day per cow)
Available bio-slurry per day	[(70-80)% of total manure produced]
Income from selling bio-slurry per month	[(Available bio-slurry $\div$ 50) $\times$ 300 $\times$ 30]
Total income per month in BDT	(Income from selling electricity + Income of selling bio-slurry)
Break-even point	(Total cost $\div$ Total income from the proposed biogas plant)



**Figure 6.** Emission of pollutants from fossil fuel

Installation of a biogas plant can create the door of opportunity for the people. For example, they can earn extra money by opening a charging station or supplying biogas for cooking in their locality. However, they can support their home as well as the area with the electricity produced from the biogas along with grid electricity connection. From the educational point of view, it can make a good impact on the society as the student can get more time to study. In a word, it can be said that a biogas plant can bring blessings to the society in a greater sense for Bangladesh.

**5. CHALLENGES**

The establishment of a biogas plant in a selected area is a quite challenging task. There are so many factors which will come in the way of this establishment as a token of a hindrance.

- The first challenge is to reconstruct a rule and support the rule for the better implementation and smooth implementation of this system. The policy and regulatory only allow the risk-free system that will satisfy the demand as per the requirement. But in practice, it is not possible for any system. Introducing and executing the system by keeping the expense within the limit is a major challenge.
- Developing countries like Bangladesh does not have the proper technical facility to provide the technical support, accessories in every corner of the country and also upgrade the plant technically. So to import new technology so rapidly and adapt to them is a challenging task.
- In urban area due to superstitions and cultural and religious obstacles, many people are keeping their distance. The powerful political person in the area motivated others against this system from the fear of losing their autorickshaw charging business. To overcome those difficulties is also a challenging task.

## 6 CONCLUSION

In present days, everything is directly or indirectly dependent on the electricity. But the difference between electricity generation and demand for electricity is too high. As a renewable source of energy biogas can serve the purpose to solve such energy-related problems in Bangladesh. Also, biogas has the potential to transform Bangladesh into self-dependent on energy. In this study, a biogas plant is proposed on a selected area for charging the battery of autorickshaw along with the feasibility and challenges study. Further research and co-operation can improve the system and popularity among the major percentage of the population.

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Auto-rickshaw

در جهان امروز، انرژی برای حفظ سطح راحتی و زندگی انسان ضروری است. از سوی دیگر، بحران انرژی یک مشکل عمده در بسیاری از کشورهای در حال توسعه همانند بنگلادش است. دلیل احتمالی این است که کاهش سطح منابع انرژی متعارف و کمبود ابتکارات برای معرفی منابع جایگزین انرژی. علاوه بر این، روش ناکارآمد و غیرقانونی استفاده از انرژی به بحران انرژی کمک می کند. در این مطالعه، سناریوی کنونی تولید برق و استفاده از آن در بنگلادش بررسی شده است. به نظر می رسد که افزایش میزان وسایل نقلیه باطری و تقاضای آنها برای برق یکی از دلایل اصلی کسری بودجه در کشور است. فناوری بیوگاز به عنوان یک منبع انرژی تجدید پذیر. و با پتانسیل میتواند به عنوان یک راه حل کارآمد و مناسبی برای بحران انرژی باشد. برای مطالعات بیشتر، به امکان سنجی انجام شده نشان می دهد که تکنولوژی بیوگاز برای تولید برق به لحاظ اقتصادی امکان پذیر است. علاوه بر این، اثرات زیست محیطی، مزایای اجتماعی و چالش های مربوط به راه اندازی یک واحد بیوگاز مورد ارزیابی قرار گرفته است.

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