

Design and implementation of biogas as an efficient renewable energy resource for Pakistan prospects

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ABSTRACT

The generation of combustible gas from anaerobic biomass captivation, is a well-known technology. Using the gas for direct combustion in household stoves is general producing power from biogas is still quite unusual in most emergent countries. The focus of this paper is to implement the importance of biogas as a substitute energy source. Bio-resources are available wide-reaching in the appearance of lasting agricultural biomass and wastes which can be deformed into biogas. Cow manure has been used for production of biogas and generation of electricity. The basic problem faced during the production of electricity is the production of biogas through anaerobic respiration which is the mixture of methane and other undesirable gases. The scrubber employed to remove the undesirable gases is very expensive and needs regular maintenance. A tap system at the top of the digester is used to remove moisture and a bucket filled with iron sponges is used to remove hydrogen sulfide. In the end, we are left with methane and some inert gases which have no adverse effect on combustion. This purified gas is used to produce electricity which is used to run the load. The benefit of this research is that this method is easily and commonly used by villagers without any hurdles.

Keywords: Biogas, Biomass, Greenhouse Effect, implementation, Sponges, Renewable energy

INTRODUCTION

Recently, all the under developing countries of the world are confronting the problem of an energy crisis. Fossil fuels that comprise oil and natural gas are deliberated as the depleting assets, therefore, the researchers and practitioners are in the search for new energy sources. In an attempt to decipher the energy crisis, renewable energy resources such as solar, hydropower, wind, and biogas are the prospective candidates that can wrestle the ever-increasing energy demands sustainably. Biogas has globally emerged as a renewable energy source which is derived from the plants (using the photosynthesis process) and the wastes of the animals and human beings (Wright et al., 2009). The other sources of biogas are the industries and municipal wastes that mainly contain methane (50-70%), carbon dioxide (20-40%), and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulfide, and water vapors (Clifton-Brown and Lewandowski, 2000). The effective operations of biogas plants can yield myriad benefits that are ultimately beneficial for the community. Also, the biogas plants conserve energy resources and help in environmental protection (Qaidi et al., 2022c, Qaidi et al., 2022a, Al-Tayeb et al., 2022, Qaidi et al., 2022d, Almeshal et al., 2022, Qaidi et al., 2022b, Aisheh et al., 2022). The temperature range of Pakistan (i.e., 30°C to 45°C) is well-suited to the fermentation of organic materials. Therefore, biogas is considered as an appropriate choice that curbs the energy crisis issue of Pakistan. For the production of biogas, anaerobic digestion is one of the widely used methods that break the animal or food waste to harvest biogas and other bio-fertilizers. In Pakistan, the easily available organic wastes for biogas fermentation are cow dung, poultry waste, water hyacinth, straw, weeds, leaf, human and animal excrement, domestic rubbish, and industrial solid and liquid wastes (Goodall, 2010). The production of biogas systems is beneficial in all terms, like; eliminating greenhouse gas, reduction of odor, the betterment of fertilizer, and production of heat and power, etc. Typically, the efficiency of biogas plants depends upon the type of digester, the atmospheric conditions, temperature, and the material loaded into the digester. Digester

operates in three different temperature ranges: the low temperature, psychrophilic bacteria range, which is $<15^{\circ}\text{C}$; the medium temperature, mesophilic bacteria range, which is 28 to 40°C ; and the high temperature, the cryophilic bacteria range, which is 49 to 55°C . Higher temperature range creates superior capacity of biogas; an supplementary source of energy will likely be required to keep the digester stuffing at a constant higher temperature.

DESIGNING

A biogas plant is a complicated system, containing a range of components. The design of such a system depends on a great amount on the kinds and quantities of feedstock provided. As there are so many various feedstock kinds appropriate for absorption in biogas plants, there are, similarly, different methods for handling these feedstock and various digester structures and schemes of operation. Moreover, reliant on the type, dimensions, and operational situations of each biogas plant, different methods for conditioning, (Heinberg and Fridley, 2016) loading, and operation of biogas are probable to implement. As for storing and operation of digestate, this is mainly concerned with its utilization as enriched and the essential ecological shield measures linked to it (Nader, 2010). Figure 1 shows the main components of the biogas plant. The moveable drum biogas plant consists of a mixing tank, digester, and gas collecting tank. Cylindrical shaped, well type digester is constructed and a dome-shaped or cylindrical gas drum is inverted on it. This drum is mounted with the help of a guided frame (Nader, 2010). The drum is either immersed directly in a slurry or water jacket. When the gas is produced and the pressure increases, the drum moves upward and when gas is removed and pressure is released, the drum moves downward and comes back to its initial position. Fixed dome biogas plants consist of a mixing tank, a closed dome-shaped digester with a fixed rigid gas holder, and a compensating tank. The lower half of this dome-shaped construction act as a digester while gas is collected in the upper half of the dome (Connolly et al., 2016).

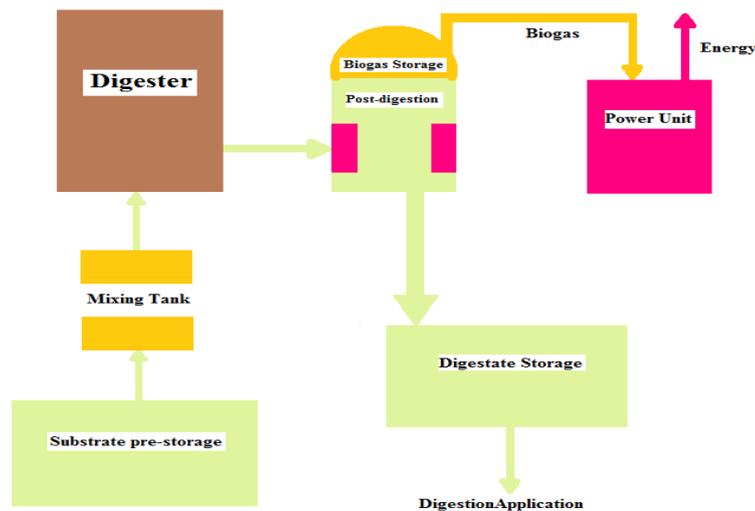


Figure 1. Components of Biogas Plant

When the gas production initiates, the slurry is moved into the compensation tank. Gas pressure varies with the changes in the volume of gas. The balloon plant biogas plant consists of a digester balloon or sack which is commonly made up of PVC in which the gas is stored. The sludge input and compensating outlet are attached directly to the balloon. The gas pressure is achieved through the flexibility of the balloon and by adding weights on the balloon (Himel et al., 2019). Balloon plants can be suggested wherever the balloon skin is not probable to be smashed and where the temperature is nearly constant and high. By keeping in view our load demand, we have designed our plant accordingly. We have chosen a moveable drum-type biogas plant for our work by keeping so many factors in our mind like feasibility, non-availability of technical staff to monitor, the temperature of our site, size of our plant, need for the constant pressure of the gas, etc (Connolly et al., 2016). According to our calculations, we have constructed our digester having 12 feet depth and 6 feet diameter. The length of the inlet pipe is 12 feet and its diameter is 9 inches. The length of the outlet pipe is 6 feet and the diameter is 6 inches. The height of the drum mounted is 4 feet and its diameter is 5.5 feet. The drum is mounted with the help of three guided frames of length 2.5 feet. A gas nozzle of 1.5 inch is mounted at the center of the drum for the extraction of gas (Jafar and Awad, 2021).

DESIGN PARAMETERS

The design constraints for any biogas system are total solid (TS) amount, temperature, PH value, C/N ratio, hydraulic retention time, etc (Rutz et al., 2008). Total solid quantity in a specific volume of resources is typically utilized as the solid component to show the biogas manufacturing proportion of the material. Below are some favorable standard parameters for our design:

Desired total solid (TS) standard value is 08%

- The most suitable temperature (T) value is 20-35 °C
- PH value should be neutral and ranges from 6.8 to 7.2
- C/N ratio has a range of 20:1-30:1
- HRT should be greater than 25 days

For cow some specifications are:

- Body weight =200 kg
- Discharge per day =10 kg
- TS=16%
- Water to be mixed to get TS value 8%-=10 kg

DESIGN OF DIGESTER

The hydraulic retention time to growth rate ratio is the safety factor of the system. The designing of digester includes the volume and cross-sectional area of the digester (Manning and Thompson, 1991). For this some quantities are as follows:

- Number of cows = 20
- Temperature = 30 °C
- HRT = 40 days
- Density = 50 kg/m³

Total discharge = number of cows*discharge/animal/day (1)

Total discharge = 20 * 10

Total Discharge = 200 kg

TS of fresh discharge = Total Discharge * TS (2)

TS of fresh discharge = 200 * 0.16

TS of fresh discharge = 32 kg

Now making favorable values to get the volume of biogas in m³ and for this we have

8 kg solid = 100 kg influent

1 kg solid = 100/8

32 kg solid = 100/8*32

Total influent required = 400 kg

Addition of water to make 8% concentration of

TS = A

A = 400 - 100

A = 300 kg

Now for calculating the volume of the digester the following Figure 2 is showing different chambers with labeled volume, height, and diameter.

Here,

V_{gs} is the volume of gas storage section and V_f is the volume of fermentation section

Total volume of digester (V_T) = V_{gs} + V_f (3)

Now volume can be calculated as,

V_{gs} + V_f = Total influent required * HRT

V_{gs} + V_f = 400 * 40

V_{gs} + V_f = 16000 kg

From standard values we can say 1000 kg = 1 m³

So,

V_{gs} + V_f = 16 m³

Geometrically we assumed,

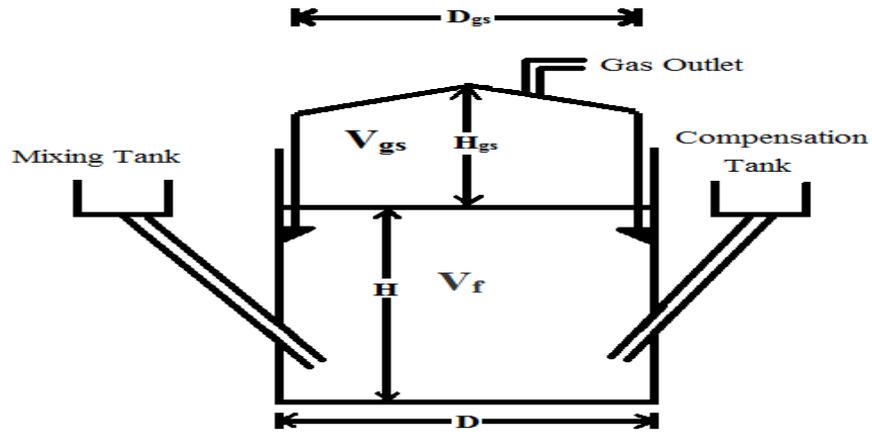


Figure 2. Digester Layout

$$V_{gs} + V_f = 80\% V_T \quad (4)$$

Or,

$$V_{gs} + V_f = 0.8 V_T$$

$$V_T = 16/0.8$$

$$V_T = 20 \text{ m}^3$$

Assumptions,

$$D = 1.48 V_T^{1/3}$$

$$H/D = 2$$

$$H_{gs} = 0.33 H$$

$$D_{gs} = 0.916 D$$

Considering assumptions and after calculations, values comes out to be

$$D = 1.8288 \text{ m}$$

$$H = 3.6576 \text{ m}$$

$$H_{gs} = 1.21 \text{ m}$$

$$D_{gs} = 1.6764 \text{ m}$$

GAS PRODUCTION

Table1 shows complete detail of 20 cows and dung from each cow per day is 10 kg. Slurry is made of 50% water and 50% dung so from 20 cows we have 200 kg slung 1 kg of cow

dung=0.05 m³ of biogas

200 kg of cow dung = 0.05 * 200 = 10 m³

From above calculations, we get 10 m³ of biogas per day.

Table 1.Production Characteristics

| Daily Fresh Dung (kg) | Volume of Digester Chamber (m ³) | Gas Production (m ³) |
|-----------------------|--|----------------------------------|
| 75 | 8 | 3.75 |
| 100 | 10 | 5 |
| 150 | 15 | 7.5 |
| 200 | 20 | 10 |

GENERATOR

As the volume of the digester is 20 cubic meters from which average biogas is 8 cubic meters. We know that

1 m³ = 1.6 kV/hr

8 m³ = 12.8 kV/hr

We are supplying electricity to 2 ceiling fans and 6 energy savers

Electricity consumption of 1 ceiling fan=80 Watt

Electricity consumption of 2 ceiling fan=80 * 2 Watt = 160 W

Electricity consumption of 1 energy saver = 20 Watt

Electricity consumption of 6 energy savers=20 * 6 = 120 watt

Total Electricity consumption =280 Watt

IMPLEMENTATION

Mixing tank of 3.5ft height, 2ft length, and 2ft width is constructed for the preparation of the slurry. Slurry constitutes water and cow dung Figure 3.



Figure 3. Construction of mixing tank

We have given our outlet pipes into the nearby crops instead of constructing the compensation tank for the collection of waste coming out of the digester. 12.5ft digging is done with the help of a crane for the construction of the digester. A digester is constructed with the help of bricks, sand, and gravel. Two pipes, one inlet pipe, and other outlet pipes are installed. The Inlet pipe was 12ft long and 9 inches wide. The inlet pipe is installed 2ft above the ground level at an angle of 45° . Whereas the outlet pipe 6ft long and 6 inches wide is installed n ground level at an angle of 0° (Himel et al., 2019). Construction is completed in 15 days. We have given our outlet pipes into the nearby crops instead of constructing the compensation tank for the collection of waste coming out of the digester. The outlet pipe has been installed having 6 ft length and 6 ft width at ground level having 0° angel. We have used a generator of a rating of 0.85 kVA for the production of electricity. The starting fuel of the generator is petrol. When the generator becomes stable, the fuel switch is converted to biogas. The voltages produced are 220 V and the current is 4.545 A with power factor 1. A floating drum of steel, having thickness 16 gauge is mounted with the help of 3 guided frames of height 2.5ft. The floating drum is 4ft high and 5.5ft diameter is used. A gas nozzle of 1.5inch is mounted at the center of the drum for the extraction of gas shown in Figures 4 and 5 respectively (Zaman, 2007).



Figure 4. Pipe for Digestate



Figure 5. Drum Fitting

ECOLOGICAL PROFITS OF BIOGAS

Biogas, a maintainable renewable source, has optimistic ecological effects at local, domestic, and global stages. Some ecological profits related to the usage of biogas technology are given below:

LOCAL ECOLOGICAL PROFITS

Substituting biomass technology with biogas could support to resolve any issues that are usually found with biomass oils. The inside air worth of houses will be affectedly enhanced as a result of consuming biogas stoves instead of burning wood, grass, and manure bundles. Due to this many of the issues with unsafe smoke matters can be escaped.

DOMESTIC ECOLOGICAL PROFIT

From a domestic viewpoint, biogas structures have assisted to decrease the burden on forestry. This has significant suggestions for crisis management and soil corrosion. Besides, usage of bio-slurry has decreased the depletion of soil nutrients by supplying naturally rich nutriments causing enlarged crop harvest and therefore lessens the burden to grow cropland, the major reason for deforestation in Pakistan.

GLOBAL ECOLOGICAL PROFIT

Biogas fuel aids to decrease greenhouse gas discharges by relocating the ingestion of fuel wood, agrarian deposits, and paraffin oil. The biogas utilized in a maintainable source promises the carbon dioxide, related to biogas ignition will be reabsorbed in the method of the development of feed and diet for animals.

GAS UTILIZATION BOILERS

Biogas can be used for all applications designed for natural gas, subject to some further upgrading, as not all gas appliances require gas with the same quality standards. Biogas can be used for heating using boilers. The heat has many applications such as being used in the plant or producing water vapor for industrial processes (Smith et al., 2000, Leduc et al., 2010). Boilers do not have a high gas quality requirement. It is preferable to remove the hydrogen sulfide because it forms sulfurous acid in the highly corrosive condensate. It is also recommended to condense the water vapor in the raw gas.

FINANCIAL ANALYSIS

Financial analysis depends upon the different factors, like material cost, full cost, and payback time.

MATERIAL COST

Table 2 shows that how much material has been used. In 4500 bricks have been used it has cost of 44K, 20 begs of cement used which has the cost of 13K, 500 boxes of Sand used it has the cost of 7500. And the other different materials have also been used in it presented in table 2.

Table 2. Material Cost

| Material | Quantity | Cost (Rs) |
|-----------------|-----------------|------------------|
| Bricks | 4500 | 44,000 |
| Cement | 20 (bags) | 13,000 |
| Sand | 500 (boxes) | 7500 |
| Gravel | 200 (boxes) | 4000 |
| Pipes | 3 | 3000 |
| Steel Angles | 3 | 1000 |
| Stands | 4 | 1000 |
| Drum | 1 | 25,000 |
| Steel Buckets | 2 | 3000 |
| Generator | 1 | 23,000 |

| | | |
|--------|---|-----------|
| Wiring | - | 2000 |
| Load | - | 2000 |
| Total | | = 128,500 |

Full Cost Analysis

Full cost analysis illustrated in table 3, the total expenditure is 167,500 which consist of labor, fitting, material, wiring and fuel cost.

Table 3. Full Cost Analysis

| Digging Cost | 7000 |
|---------------------|-------------|
| Labour Cost | 25,000 |
| Fitting Cost | 5000 |
| Material Cost | 128,500 |
| Wiring Cost | 1000 |
| Fuel Cost | 1000 |
| Total | = 167,500 |

Payback Time

Generator of 0.85 kVA is running almost fourteen hours per day so the total power produced

$$\text{Total power produced} = 0.85 * 14$$

$$\text{Total power produced} = 12 \text{ units/ day approx.}$$

$$\text{Total number of units produced monthly} = 12 * 30$$

$$\text{Total number of units produced monthly} = 360$$

$$\text{Per unit cost} = \text{Rs. } 15 \text{ approx.}$$

$$\text{Total cost of units produced} = 360 * 15$$

$$\text{Total cost of units produced} = \text{Rs. } 5400$$

$$\text{Annual Cost} = 5400 * 12$$

$$\text{Annual Cost} = 64,800$$

Now capital cost of biogas plant is Rs. 167,500.

Hence the payback time is

$$\text{Payback Time} = 167,500 / 64,800$$

$$\text{Payback Time} = 2.58 \text{ yrs} = 32 - 35 \text{ months}$$

COMPARISON B/W BIO GAS AND SOLAR CELL

By different cost analysis the comparison between bio gas and solar cell have been analysis in this section.

Replacement Cost

It is the actual cost to replace a plant or structure at its pre-loss condition. It can be different from market value (Leduc et al., 2010).

Operating & Maintenance Cost

It means all actual cash or amount for operation, maintenance, and administrative costs relating to the system.

Liveliest Cost

It is the cost of electricity it is a measure of a power source which attempts to compare different methods of electricity generation (Heinberg and Fridley, 2016). Table 4 shows the comparative analysis between the 15MW of solar and biogas power plant to know which plant is best.

Table 4 Comparison of 15 MW of Solar and Biogas power plants
Comparison B/W Biogas and Wind Power

So, from the table, we can see that the biogas plant is more efficient and less costly. Although, solar cells and wind power has their importance, but they cannot be building up in

| Parameters | Biogas plant | Solar cell |
|---------------------|------------------------|--------------------------------------|
| Cost of Investments | 35.55m\$ | 75m\$ |
| O \$ M Cost | 2.9m\$m\$ | 1.92m\$ |
| Replacement Cost | 5.5m\$ | 35.35m\$ |
| Levelised Cost | 26.2cents/kWh | 30.1cents/kWh |
| Efficiency | Over 40% | 25% |
| Feasibility | It can build any place | Where solar energy is in large scale |

ant location. The biogas power plant has less cost and the minimum is size. In a comparison of solar and wind, it can build in small areas. It has more efficiency than wind and solar. It has one disadvantage that it is not odorless (Li et al., 2005).

RECOMMENDATION

To reduce the energy crises in Pakistan, cow dung, poultry waste, water hyacinth, straw, weeds, leaves, human and animal excrement, home trash, and industrial solid and liquid wastes are the readily available organic wastes for biogas production in Pakistan.

CONCLUSION

The current energy consumption positions in different farms and houses, the economic feasibility of the least possible sizes of biogas plants for various situations, and the perspective of electricity production from animal waste. The paper has exposed that there is a prospective to generate power from animal waste and there is great attention from villagers to generate electricity. This attention has originated due to the reality that all the villagers experience load cracking all over the day typically in the evening which blocks their work. From the paper and its results, electricity can be generated from animal manure for the total daily ingestion of many houses and in accumulation power can also be generated for the topmost hour only to save houses from being scratched off Energy savers can be used in every house rather than tube lights as the purpose of lamps is illumination only, not reheating. The ability of many biogas plants fitted in villages is measly than its entire prospect. Generating power is more substantial than utilizing biogas for cooking purposes. At the current state, there is no profitable worth of animal dung as fertilizer in common. Meanwhile, villagers are not conscious of the worth of the dung as biological fertilizer and the current rule does not certificate to trade biogas dung in the market excluding patent. The equipment utilized in the industry to generate power is not confirmed yet as it is comparatively original in the state. Nevertheless, the technology utilized in BETA PAK projects is more technical than others. The major obstacles to the distribution of the technology are the current rule for promoting manure as biological fertilizer and the absence of consciousness of the villagers consuming manure. Furthermore, the equipment itself is an obstacle as it is not confirmed up till now. Moreover, the initial venture charge for the installation is also an obstacle for the farmers and villagers. An economic study was complete for plants having twenty to thirty cubic meters of the digester. From the analysis, it was concluded that energy production for twelve hours all over the day is economically more viable than for six hours in the evening. Only energy as a product to receive income cannot conclude its feasibility for fifty kilograms and below manure amount in any situation.

Adding carbon dioxide prices with the price of electricity still cannot conclude its feasibility regardless of the manure amount. Nevertheless, for two hundred kilograms and above can lead to power generation. In the accumulation of peat charge with energy, charge marks the project viable for the farms with a capability of five hundred kilogram plants and above. Accumulation of carbon dioxide charge with peat and energy cost marks the plan extra cost-effective for the above situations.

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