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

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Submitted : 04-05-2022

Revised : 29-08-2022

Accepted : 10-09-2022

ABSTRACT

The generation of combustible gas from anaerobic biomass captivation is a well-known technology. Using gas for direct combustion in household stoves in 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 availably wide-reaching in the appearance of lasting agricultural biomass and wastes which can be deformed into biogas. Cow manure has been used for the production of biogas and the 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 with the problem of an energy crisis. Fossil fuels that comprise oil and natural gas are deliberated as depleting assets, therefore, researchers and practitioners are in search of 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 with the ever-increasing energy demands sustainably. Biogas has globally emerged as a renewable energy source that is derived from plants (using the photosynthesis process) and the wastes of 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., 30ºC to 45ºC) is well-suited to the fermentation of organic materials. Therefore, biogas is considered an appropriate choice that curbs the energy crisis issue in 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, 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 <15ºC; the medium temperature, mesophilic bacteria range, which is 28 to 40ºC; and the high temperature, the cryophilic bacteria range, which is 49 to 55ºC. A higher temperature range creates a superior capacity for biogas; a 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 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 operating 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. A 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).

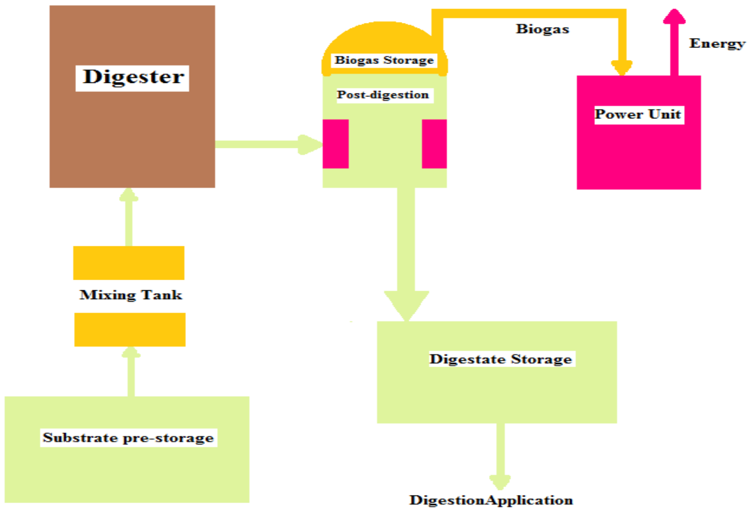

Figure 1. Components of Biogas Plant

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 to 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 12 feet in depth and 6 feet in 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 inches 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). The 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
- The C/N ratio has a range of 20:1-30:1
- HRT should be greater than 25 days

For cows 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 design 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/m^3

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 m^3 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 an 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,

Vgs is the volume of gas storage section and V_f is the volume of the fermentation section

The total volume of the 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 m^3

So,

$V_{gs} + V_f$= 16 m^3

Geometrically we assumed,

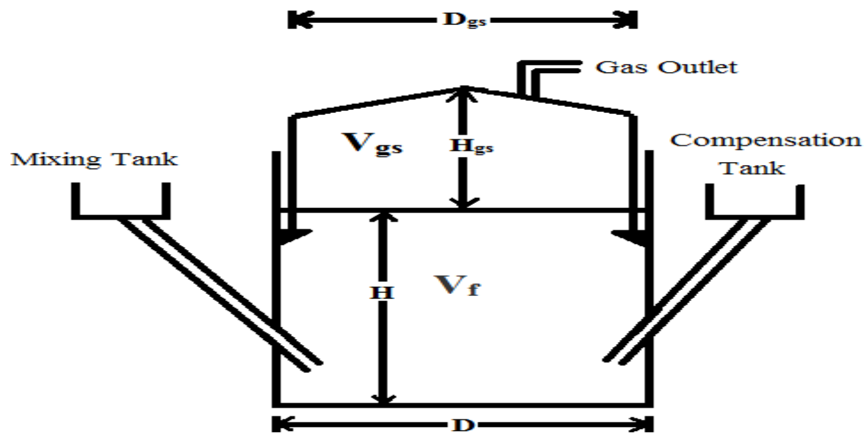

Figure 2. Digester Layout

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

Or,

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

$V_T = 16/0.8$

V_T = 20 m3

Assumptions,

D = 1.48 $V_{T1}/3$

H/D = 2

H_{gs} = 0.33 H

D_{gs} = 0.916 D

Considering assumptions and after calculations, values come out to be

D = 1.8288 m

H = 3.6576 m

H_{gs}= 1.21 m

D_{gs} = 1.6764 m

GAS PRODUCTION

Table 1 shows complete detail of 20 cows and dung from each cow per day is 10 kg. The slurry is made of 50% water and 50% dung so from 20 cows we have 200 kg slung and 1 kg of cow dung=0.05 m^3 of biogas

200 kg of cow dung = 0.05 * 200 = 10 m^3

From the above calculations, we get 10 m^3 of biogas per day.

Table 1. Production Characteristics

Daily Fresh Dung (kg)	The volume of the Digester Chamber (m^3)	Gas Production (m^3)
75	8	3.75
100	10	5
150	15	7.5
200	20	10

GENERATOR

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

1 m^3 = 1.6 kV/hr

8 m^3 = 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

A 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 another outlet pipe 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° angle. We have used a generator with 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 a thickness of 16 gauge is mounted with the help of 3 guided frames of height 2.5ft. The floating drum is 4ft high and a 5.5ft diameter is used. A gas nozzle of 1.5 inches 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

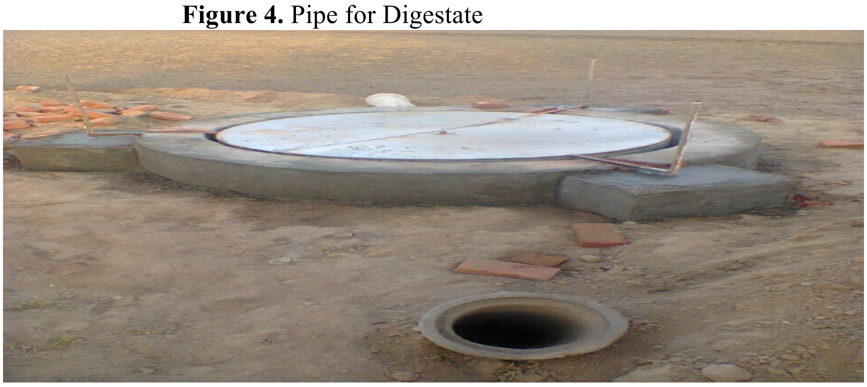

Figure 5. Drum Fitting

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 solving any issues that are usually found with biomass oils. The inside air worth of houses will be affected and 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 lessening 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

The financial analysis depends upon different factors, like material cost, full cost, and payback time.

MATERIAL COST

Table 2 shows how much material has been used. 4500 bricks have been used at a cost of 44K, 20 bags of cement used which has a cost of 13K, and 500 boxes of Sand used as 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 is 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

A generator of 0.85 kVA is running almost fourteen hours per day so the total power produced Total power produced = 0.85 * 14

The total power produced = 12 units/ day approx.

Total number of units produced monthly = 12 * 30

Total number of units produced monthly = 360

Per unit cost = Rs. 15 approx.

Total cost of units produced = 360 * 15

Total cost of units produced = Rs. 5400

Annual Cost = 5400 * 12

Annual Cost = 64,800

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

Hence the payback time is

Payback Time = 167,500 / 64,800

Payback Time = 2.58 yrs = 32 – 35 months

COMPARISON Between BIO GAS AND SOLAR CELL

Through different cost analysis, the comparison between biogas and solar cell has been analyzed 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 is a measure of a power source that 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 Between 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 have their importance, they cannot be built up in any 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 it is not odorless (Li et al., 2005).

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

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. In 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 certify to trade of biogas dung in the market excluding patents. 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 completed 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, 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 as extra cost-effective for the above situations.

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