INDIRECT SOURCE OF SOLAR ENERGY CONVERSION-SUSTAINABLE BIOMASS AND BIOGAS

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ABSTRACT

In our industrialized society, it is quite difficult to maintain adequate supply of energy. As we all already know, fossil fuels are declining year by year, there is dire need to search alternative source of renewable energy. Various factors like rising population and shortage of commercial fuels in rural and traditional sectors have sustained the growing use of biomass as energy. One of most common alternative source of energy is Biomass. There are several source of converting biomass into biogas and many useful products. An attempt has been made to study on various sources such as water hyacinth, algae, grass, trees etc. The study emphasis on methods to generate biogas for cooking and lighting. Biomass plays an important role to act as renewable energy and assume to be best substitute for use of fossil fuels. Biomass proves to be solving many environmental issues especially global warming, reducing green house gas emission and sustainable development among poor nations. The study reveals the various types of biogas unit used in India such as floating and fixed dome type biogas plant and compares it with other biogas unit available in the market. No doubt, energy from biomass is more reliable as it is free from fluctuation like wind energy.

Keywords: Solar Energy; Biomass ; Sources; Biogas unit; Energy generation

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INTRODUCTION

Solar energy is the ultimate source of most forms of energy and widely used as clean, safe and viable quantities in many parts of world. Sun's energy has been used by both nature and man to synthesis food. Its energy is utilized in power refrigerators and help to operate pumps, sewage treatment plants. Solar energy can be trapped as heat called photo thermal process or can be directly undergo electric conversion called photovoltaic process. Other process such as photochemical in which solar energy is stored in the form of chemical energy. In this mode, energy is utilized in atomic and molecular system which undergoes chemical changes and result in the formation of biomass. This biomass is further processed to produce more convenient gaseous or liquid fuels. The overall pathways for biomass generation can be described as-

Solar energy $\longrightarrow$ Photosynthesis $\longrightarrow$ Biomass $\longrightarrow$ Energy generation

In this mechanism, the first step to produce biomass is the trapping of sunlight to produce sugar and starches from plants through the process of photosynthesis. For biomass generation, photosynthesis is the biological conversion of solar energy into carbohydrates and energy rich compounds. Intensity of solar light having wavelength around 400-700A^0 is an important requirement for generating carbohydrates [1]

$$\text{Light} + CO_2 + H_2O \longrightarrow \text{Carbohydrate} + O_2 \quad \text{(Photosynthesis)}$$

The oxygen liberated is from H_2O and not from CO_2 molecule. This process is called CO_2 assimilation. CO_2 is an essential requirement for the growth of plant. In normal healthy atmosphere, the concentrations of CO_2 is 0.03-0.04%. The increase in concentration of CO_2 can be achieved by animal respiration, by using organic manure, by combustion of fossil fuel. Such a technique of harnessing solar energy into renewable form of energy which is used in domestic purposes.

The term "Biomass" includes all plant life- Trees, Bush, algae, agricultural crops and their residue. The residue means crop residue or agro processing residue such as husk, molasses, oilseed shells, sawdust etc. Biomass also includes human excreta, household waste, industrial waste or sewage sludge. The resources of biomass can be categorized as:

(i) Traditional solid mass i.e. wood and agricultural residue.

(ii) Non-Traditional form.

Traditional solid mass can be burned directly to produce energy while Nontraditional form is converted to ethanol and methanol, used as liquid fuel in engines. When this biomass undergoes an aerobically fermented, it produces gaseous fuel called biogas. Earlier, biogas is produced from domestic and farmyard waste and gets utilized in rural areas. There are generally three ways to obtain energy from biomass. These may be thermo chemical route, biochemical route or oil extraction. In thermo chemical route, it includes process like combustion, gasification and pyrolysis. Combustion generally proceeds with complete burning of biomass to heat and power. In combustion, wood, agricultural waste, dung waste are most commonly used fuel. For better result, some special species of trees such as Eucalyptus, babool,casuarinas are grown and harvested at regular interval of time so that wood is available all the season for cooking purposes[2]. Gasification involves burning of solid biomass in limited supply of air while Pyrolysis is the process of burning of biomass at very high temperature in the absence of oxygen and result in the formation of charcoal and high volatile gaseous products.

Materials for Biomass production: There is long list of sources of biomass generation. The material generally used is cow dung and poultry droppings which are conveniently converted into biogas. Many other material such as algae, crop residue, agro waste, paper waste, human waste, trees or any cellulosic material of animal or plant origin are used for generation of biogas. There are some important sources of biomass summarized in the figure 1.

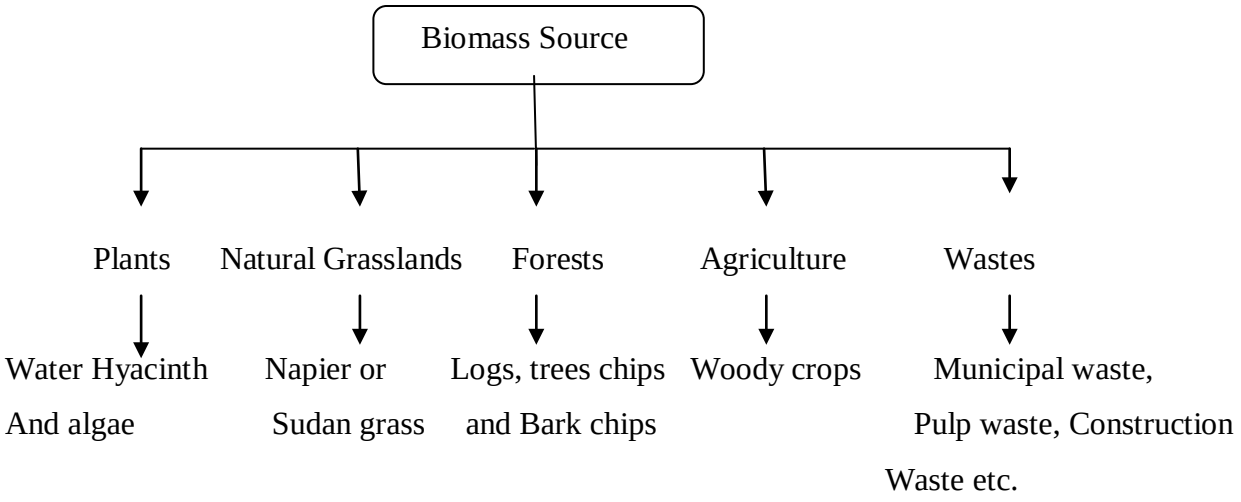


Fig.1 Biomass Source

1. Water Hyacinth: Water hyacinth is a major source of biomass which can be converted into methane and used as a nutritive food. It is generally found in rivers of hot region of world. This water plant is fresh water macrophyte and botanically named as: Eichhonia Crassipes" as in figure 2. The study reveals that anaerobic filter digester produce 130 litres of methane per one kilogram of volatile solids for 10 days and biogas produce contain approximately 65% methane [3]. Water hyacinth produce 350 to 450 litres of biogas per kg of dung solids. Water hyacinth is used as good food, fertilizers and biogas producer. It is also used in paper production. This floating plant can be used as feedstock for local energy production and produce important products with special environmental and ecofriendly sustainable benefits. Water hyacinth has rich in quantity of cellulose, lignin etc. which is much lesser in cow dung (locally practiced energy production process). Thus, this plant not only produce methane gas which is used for cooking but its residue after digestion provide fertilizer rich in nutrients [4]

Fig. 2 Water Hyacinth

2. Algae: Algae is single cell plant which has high protein content. Algae are generally grown on open setting ponds, but its yield is much poor. Some varieties such as ulothoria, spiruiina, scenedesmus have higher yield. Algae can be burned directly or an aerobically fermented to produce methane. Generally, dry algae can produce 3300 Kcal per kg. Algae biofuels are nontoxic and biodegradable. They contain no sulphur and produce energy as much when we compare with conventional fossil fuels [5].

3. Natural Grasslands: Agronomically managed, perennial grasslands produce higher biomass yield. Perennial warm season tall grasses are potential source of better yield and quality. These grasslands assumed to be lower operating cost than Convention row crops and thereby reducing fuel and labour expenses[6] These grasses need much less water than marine plants and secondly, they are periodically harvested leaving the stubbles to grow again. Grass species such as Napier grass, Sudan grass give best yield. Here is given natural

Fig. 3 Natural Grassland

grassland in figure 3 These grasses after cutting get dried and compacted to be used as fuel or mixed with water to form slurry to be introduced in biogas digesters.

4. Trees: The most prominent source of wood is trees. By using solar energy, wood be burned in boilers for power production. Actually, wood is free from sulphur and ash obtained after burning can be used as fertilizers. Some species of tree with their biomass are given in Table 1 as:

Table 1: Trees with biomass yield

Species	Yield (tone/acre/year)
Eucalyptus	24.1
Sycamose	11.2
Conifers	5.4
Cotton wood	3.1

Out of the above, Eucalyptus has maximum yield rate. These trees are cut for wood and stumps grow back to size before next cutting.

5. Agriculture: Crops are grown specifically as a fuel and provide high output per hectare. The byproducts are agriculture residue, important energy conversion technology. This agriculture residue may be dry residue such as husks, animal manure or slurries, poultry litter. Wet residue includes animal slurry and farmyard manure or grass silage. Care must be taken when using wet residue, moisture content must be removed before digestion otherwise it reduces energetic efficiency. Also in gasification process, there must be minimum moisture content.

6. Waste: Waste includes Municipal solid waste such as oil/fats, pulp waste, construction material waste which are produced from industry or other domestic operation. These waste and residue has valuable energy content [7]. Many industrial byproducts can be converted into biomass fuel. Industrialized waste can be woody or nonwoody waste. Woody waste could be wood composites, untreated wood. Nonwoody waste includes paper pulp, sewage sludge or textile, can be potentially used as biomass fuel.

Conversion of biomass into energy-Biogas plant: In India, biogas technology starts in the year 1937 when municipal sewage sludge undergoes anaerobic digested. There are various types of material used for biogas generation such as cow dung, waste include wet organic waste. When wet organic waste is undergone digested, it produces 50% methane. The composition of biogas

depends upon digestion process. In normal digestion process, biogas has methane concentration 55-75%. Typical composition [8] of biogas are summarized in table 2.

Table 2: Composition of biogas

Compound	Percentage
1. Methane(CH_4)	50-75
2. Carbon dioxide(CO_2)	25-50
3. Nitrogen(N_2)	0-10
4. Hydrogen(H_2)	0-1
5. Hydrogen sulphide (H_2S)	0-3
6. Oxygen(O_2)	0-0

There are various types of biogas unit developed which subsequently improved and designed at different stages. Earlier, Khadi and village industry (KVIC) developed a floating dome shaped biogas plant (called as Grah Luxmi).

1.Khadi and village industry (KVIC) Biogas type: In KVIC type, there is basically two basic components a) digester pit b) Dome. Digester is a well containing animal waste in the form of slurry and dome is that which floats on slurry and act as gas holder. The container at which digestion of sludge containing a large amount of complex organic matter (carbohydrates, proteins, fats) takes place at ambient temperature of 35-70^0 C is called digester and process is called anaerobic digestion. The flow chart of anaerobic digestion takes place as in figure 4.

After the complex organic molecule undergoes enzymatic hydrolysis, it breaks down into simple organic molecule, it passes through two stages:

i) Acid fermentation: Simple organic substances in waste are acted upon by special kind of bacteria called acid former which broke up into simple acids.

ii) Methane Formation: These simple acids are again acted upon by bacteria to produce methane and carbon dioxide [9].

Complex organic matter

(Fats, proteins, starches)

Enzymatic Hydrolysis

↓

Simple organic compounds

(Sugar, amino acids, fatty acids and volatile solids)

Bacterial Fermentation

↓

Methane and carbon dioxide

Fig.4 Anaerobic Digestion

The biogas generated has calorific value around 16000 to 25,000 kj/m^3.It is excellent fuel for cooking and lighting. For efficient generation of biogas, Following are condition:

- There should be pH value around 6.5-8 for efficient production of biogas.
- Optimum temperature must be between 35-38^0 C for working of methane bacteria. Lowering the temperature, lesser will be the yield of biogas and even production will be stopped at a temperature of 10^{0}C.
- A specific ratio of carbon to nitrogen (C/N) must be kept between 25:1. Normally 1 Kg of dry cattle requires 1000 ml of eater to produce 1 m^3 of biogas.

Working of KVIC: It consists of a digester which is made of masonry work and built below the ground level. There is partition wall in the centre which divide digested well vertically into two semi cylindrical compartments. There are two slanting cement pipes for inlet and outlet purpose. A mixing of cow dung and water in the ratio of 4:5 flows through inlet pipe into digester as in figure 5. When both the compartments of digester pit are full, then equivalent amount of fermented slurry flows out at outlet. Dome is a drum constructed of mild steel sheets, cylindrical in shape with conical top radial support and fit into digester. As gas

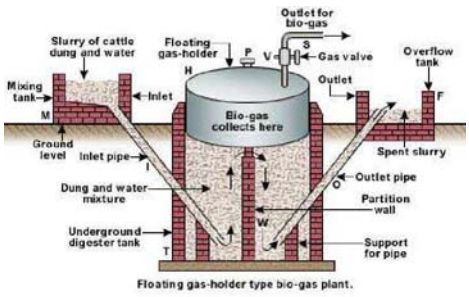


Fig. 5 Floating Biogas unit

is generated, gas holder (dome) rises and float on slurry. A pipe is provided at top of dome for gas collection. A central guide pipe is present to prevent the holder from tilting. The gas escape out passed through soda lime to make it dry.

2. Fixed Dome type biogas plant: It consists of well shaped like underground tank made of bricks and cement called digestive tank provided with inlet and outlet valves. The roof of tank is dome shaped. A gas outlet is provided at top for collection as shown in figure 6. There is mixing tank above ground levels which is connected to inlet valve of digester through slanting inlet chamber. The outlet chamber is connected to overflow tank which collect used slurry. When animal dung is mixed with water to make slurry and carried to digester tank [10]. The slurry is left for two months for fermentation by aerobic microorganism which produces biogas and collects in dome. It exerts a large pressure on slurry and forced to go in overflow chamber. The biogas is collected through a pipe and used for cooking. There are some difference between floating and fixed dome [11] unit as in Table 3

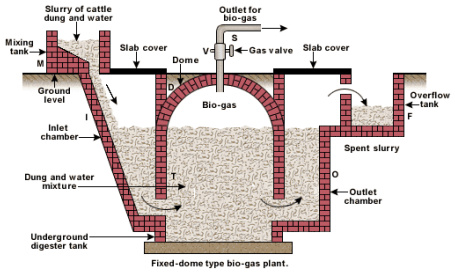
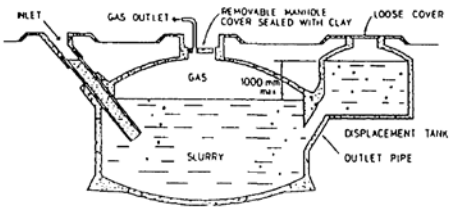


Fig. 6 Fixed Dome Unit

Table 3: Difference between floating and Fixed Dome:

Floating	Fixed Dome
1. Drum consists of masonry digester with steel, plastic or gas holder.	1. It consists of masonry of concrete structure.
2. High cost.	2. Low cost
3. Require more maintenance.	3. Require less maintenance.
4. More reliable	4. Low reliability.
5. Does not require high supervisory skill.	5. Require high supervisory skill.
6. Life span is short.	6. Life span is longer than floating type.
7. Gas pressure remains constant about 10 cm of water.	7.Gas pressure varies between 0-90 cm of water

3. Chinese Type Biogas Plant: Its design consists of fixed dome for collection of gas. Its cost is very much low



and construction is quite easier. For construction of 2 m^3 of Chinese plant, its cost just Rs. 2500/- but for KVIC Cost around 5500/-.So, it replaces the floating drum of KVIC digester. A view of Chinese biogas unit is shown as in figure 7.

Fig. 7 Chinese Biogas Unit

4. Deenbandhu type plant: Another most popular biogas plant is Deenbandhu model. It has a hemispherical fixed dome type. The dome is made of reinforced concrete and attached to the digester. After fermentation under anaerobic condition, gas is collected at top of dome while sludge comes out through an opening inside of digester. Its cost is much less than KVIC or Chinese type.

CONCLUSION

Biogas plays an important role to act as renewable energy and assume to be best substitute for use of fossil fuels. The increasing interest in biomass energy and biofuels has wide benefits [12] such as reduction in green house gas emission, substitute for diminishing oil supply, convert waste into energy and energy security. Biomass delivers most energy for domestic use in rural area (approx.90%). Wood fuel contributes 56% of total biomass energy and consumption of wood has grown annually at 2 percent rate over the past two decades. Biomass from agro-waste is available during harvesting season, so there is need to save our desired quantity of biomass in harvesting months. Government should have to adapt policy to use biomass with high potential benefits. These technologies solve many environmental issues especially global warming and sustainable development among poor countries. These not only act as substitute for energy but provide employment opportunity.

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