Biogas Energy: Sustainable Option for Rural Electrification in India

Devinder Sheokand[1] Ram Avtar[2]
[1]M.Tech. Student
[1,2]UIET-KUK

Abstract— Increasing electricity demand, fuel prices and environmental concerns are the factors which motivates the use of renewable energy sources in India. Most common form of renewable energy sources are sun and wind. But biomass is one of the oldest renewable energy. It comes directly and indirectly from the plants. In last few years, India has shown growth in utilization of renewable energy sources. In India, share of renewable energy sources is almost 14% in total electricity generation. As of April 1, 2015, according to government, 18,452 Indian villages still un-electrified. This paper presents the idea of biogas power plant for rural electrification needs in India. The biogas can be produced using wood and wood waste, agricultural residues & farming manures, human waste, vegetable wastages and municipal waste. The special designed gas engine with modified piston, compression ratio, firing controller for sparkling ignition can be used. If excess biogas available, which can be used for cooking purpose by constructing common kitchens in villages by minimizing need of LPG or kerosene. The proposed system can be implemented in some potential places in Baharurpur, (Punjab), Namakkal, ottanchathiram, palani, salem, Uthukuli, (Tamil Nadu), &some part of Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, and Gujarat in India. [1][5].

Key words: Biogas, Rural Electrification, Agricultural Waste, Animal Waste, Anaerobic Digestion, Waste Heat Recovery, By-Product as Organic Manure, Biogas Generator

I. INTRODUCTION

Electricity is one of the driving forces in growing economy and increasing demand puts inconvincible pressure on countries' energy infrastructure to match demand. Depleting coal, oil and gas reserves, combined with growing concerns of atmospheric pollution, have made search for energy from renewable sources necessary.

In India, 18,452 villages still un-electrified [5]. This problem can be solved using renewable sources of energy like solar, biogas or hybrid power plants. In Indian villages, the house animals like cow, buffalos, goats, pigs, are used for milking and meat purpose. The farm houses for cow and buffalos can be found widely in India. These animal waste can cause methane production, during rainy days it pollute the local water resources like river, ponds etc. These waste will emit greenhouse gases into atmosphere if untreated [1].

Another waste material used in biogas plant are agriculture waste like rice husk, cotton stalks, straw, paddy waste. But there farming waste are burnt by farmers to eliminate waste after harvesting. These waste emit trace gases like carbon dioxide, methane, carbon monoxide, nitrogen oxide, sulphur oxide and large amount of particulate matters which affect human health as well as environment making soil fertility decreases. Government banned the burning of agriculture waste but still farmer burns these due to lack of awareness. Due to agricultural country, India has better option of biogas for rural electrification. Generated power may be distributed through grid or may be synchronized with state electricity board grid at tail end to meet the local demands.

II. SOURCES FOR BIOGAS PRODUCTION

A. *Agricultural Waste*

India depends upon farming. different types of crops are produced in different areas. Therefore, large amount of rice husk, grass, vegetable wastes, straw, paddy waste etc. may be collected from fields can also produce biogas.

B. *Animal Waste*

In India, cows and buffalos' cattle are maintained by farmers. These provide milk and meat. Disposal of wastes like dung are major problem.

C. *Poultries*

They dump their wastes in open air environment, due to chemical digestion process, the methane gas produce and mixed with atmospheric air causes odour, health issues to human being and causes the global warming effect.

D. *Human Waste*

Human waste can also use for biogas production in cooking and electrification process.

E. *Municipal Solid Waste*

most common biomass is from waste energy. It is found from waste sites such as municipal waste, manufacturing and landfill gas. Biofuels from sugar and oil are first generation biofuels obtained from sugarcane and corn in turn produce bioethanol. These fuels as gasoline. Garbage waste release methane gas which is type of biomass.

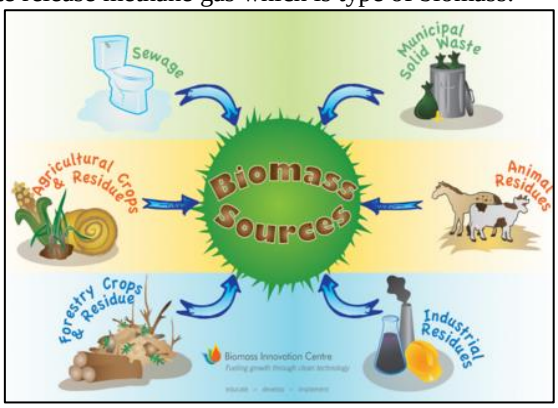

Fig. 1: Biomass sources

III. CONVERSION PROCESS

Biomass can be processed in different ways to produce biogas. Based upon available resources at nearby environment, site selection, climate condition throughout the year, the methodologies digesters can be designed for our power plant. Mainly it divides into biochemical and thermochemical conversion.

A. Biochemical Conversion

Wet biomass can be processed in anaerobic digester employs bacteria to transfer organic matter into gaseous production.

1) Anaerobic Digestion

Anaerobic digestion of organic materials by organism in the absence of oxygen. The process results in formation of biogas, a combustible gas mixture such as methane, hydrogen sulphide. It includes different types of bacteria and divided into four groups which are given below:

a) Hydrolysis

It is a chemical process in which molecules of water are added to a substance. Large, complex, insoluble compounds like protein, carbohydrate, and lipid are converted into soluble components like amino acids and sugar. [2][4]

b) Fermentation (Acidogenesis-Acid Formation)

A biological reaction where monomers are converted into volatile fatty acid. [4]

c) Fermentation (Acetogenesis-Acetate Formation)

In biological reaction, volatile fatty acid is converted into acetic acid, carbon dioxide and hydrogen.

d) Methanogens

A biological reaction where acetates are converted into methane and carbon dioxide produced as by-product.

B. Thermochemical Conversions

This technology emerged for treating applied for dry biomass (moisture content >50%) combustion to immediately release its thermal energy & gasification pyrolysis & liquefaction (temp. 800-1000^{o} C).

1) Pyrolysis

In this process, heat is applied to biomass feedstock in presences of catalyst to convert it into biofuel which is generally in nature.

2) Combustion

In this, various burner/boiler technologies are used to direct burn the feedstock like coal & natural gas & convert it into energy.

3) Gasification

In this, biomass feedstock is partially oxidised & then decomposing in a reactor vessel to produce synthetic gas.

4) Various Combustion Technologies

Different Combustion technologies are stoker Biomass co-fire and fluidized bed combustion.

5) Biomass Co-Firing

This method is developed in US and Europe trying to improve the efficiency of the system and reduction in total carbon emission during power generation in plants. In this method biomass fuel such as gas burn with fossil fuels like coal products.

6) Fluidized Bed Combustion

In this process, combustion apply a mixture of silica and limestone, a special form of biomass fuel along with air flow.

IV. GASIFICATION

It involves biomass converting into gaseous components (producer gas or syngas) by supplying limited amount of oxygen than is needed for complete combustion of fuel. These two types of gases are depending upon the reactor type (updraft, downdraft, cross draft), temperature, fuel characteristics and degree of various chemical reactions occur in process. [7]

Producer gas is a mixture of gases produced by biomass at temperature (1292^{0}C-1832^{0}C). it is composed of carbon monoxide, hydrogen, methane and CO_2 with N_2.

Syngas is a mixture of CO & H_2 by product of high temperature steam or oxygen gasification of biomass of organic materials.

A. Biogas Composition

Components	Formula	%
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-50
Nitrogen	N_2	0-5
Hydrogen Sulphide	H_2S	0-3
Oxygen	O_2	0-2
Ammonia	NH_3	0-1
Hydrogen	H_2	0-1

Table 1: Biogas Compositon

This gas can be used in different form which is given bellow:

- It is used to run internal combustion engine.
- Also used as fuel for furnace oil for direct heating purpose.
- Produced methane is used in engines and chemical industries as well.

V. CASE STUDIES

In India, Biogas Power Plants are used for utilization of different biomass such as rice husks, peat, wood, coconut husks etc. These biomass material are easily available and total availability and handily are easy and cheap. Different cases are following:

A. Case Study 1: Biomass Power Plant In Tumkur Of Karnataka

In Tovinakere panchayat, district tumkur, Karnataka was initiated a project in 2001 for rural electrification for 5 villages. Now, it consists of a cluster of 28 villages providing a source of income for 250 women in 81 self-helped groups. This produces bioelectricity using biomass for energy plantation cultivation for the purpose.

Under BERI (Biomass Energy for Rural India) project, its aim to develop & implement a bioenergy technology package to reduce GHG (Green House Gas) emission & promote sustainable & participatory approach to meeting rural energy needs.

Tree plantations grown on land of 2,930 hectares (including forest land of 1,983 hectares and tree-based farming of 947 hectares) have reduced up to 12,000 tons of carbon generated and provided livelihood for local villages. A 500 kW gasifier-based power plant is operational capacities of two gasifier systems of 100 kW, one of 200 kW (100 percent producer gas based) and other is 100 kW with dual fuel mechanism. The plants have generated 1,520,000 kWh of electricity as of June 2012, resulting in a reduction of 1,200 tons of CO_2. [2]

B. Case Study 2

Bhintbudrak is a village in Uchhal taluka of the Taapi district in Gujrat. Bhintbudrak is located almost on the Gujrat-Maharashtra border, near to the town of Navapur in

Maharashtra. In that village, it consists around 500 families (Population- around 2200), all are milk suppliers nearby Surat District Co-operative Milk Producer's Union Ltd (SUMUL). Majority of these 500-odd households are closely spaced in the heart of the village; the rest being considerably far and scattered. Figure 2.1 shows the satellite map of the village. Almost 90% of the total number of households possess cattle or other bovine animals, the number of cattle at each household ranges from 2-6. With this cattle population, that village is able to provide around 2400 litres of milk daily to the SUMUL dairy. The animal stalls are in the front yard/backyard/porch of the household in most of the cases. The animals are allowed to graze in the free pastures of the village or in some cases fed in the stall itself.

Fig. 1: Satellite map of Bhintbudrak showing closely spaced households (Source: Wikimapia)

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