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USE OF BIOGAS AS A PROMISING ALTERNATIVE OF FOSSIL FUELS IN VEHICLE ON INDIAN PERSPECTIVE: A REVIEW

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Abstract **- Use of biogas assures renewable energy supply and balances the green house gases. There is growing interest in the use of biogas as a fuel for transport applications. A compressed biogas (20-25 MPa / 200-250 bars) with high methane content (at least 97%) by volume can be a promising alternative as vehicle fuel in replacement of conventional fossil fuels. Biogas fuelled vehicles can reduce CO_2 emissions by between 75% and 200% compared with fossil fuels. This paper sets out the resource, available for producing biogas and explores how this gas can be used as fuel for transport by describing the basic technology requirements.**

Keywords **- Biogas, Renewable Energy, Alternative-fuel, Transport-application.**

1. Introduction

Energy is the backbone of developing countries like India. Conventional energy sources such as crude oil, coal and natural gas are used to fulfil increasing demands, but these resources are exhausting rapidly with pace of the time[1]. Numbers of countries in the world including India are currently passing through the critical phase of population explosion and the growing population demands more energy inputs.

Therefore there is a requirement of energy in India to satisfy the energy demand and which is Environment friendly. To fulfil energy demands of Indian population, the strategy must focus on basic seven goals which are cost minimization, efficiency maximization, employment generation, system reliability, minimization of petroleum product, maximization use of local resources and minimization of emissions[2]. Production of biogas meets all these criteria and worth using rather than natural gas because of its renewable sources.

Biogas is generated from anaerobic digestion of organic compounds such as municipal and industrial wastes, animal and agricultural residues. This renewable energy is already used for heat, electricity production and cooking. In India, Ministry of New and Renewable Energy had set a target to achieve 48.55 MW energy from biogas plants till 2022[3]. There is the tremendous potential in India as well as rest of the world in employing anaerobic digestion as waste treatment method as well as an energy production technology. The best upgrading solution of this clean energy should be the production of fuel for transport applications. Biogas fuels usually cause low pollution to the atmosphere and because they come from renewable energy resources, they have a great potential for future use. This vehicle fuel is the best way to waste management and carbon cycle balancing.

2. Raw biogas extraction

Raw biogas has been produced since the second half of the 1 9th century. India was one of the pioneering countries which were generating biogas from manure and kitchen waste for household purposes. Biogas is the gas generated from anaerobic digestion (AD) of organic matter which includes animal-human excreta, kitchen-agricultural residues, municipal wastes and algal-plant biomass etc. with balanced carbon cycle Biogas is a source of renewable energy like solar, wind and geothermal etc.

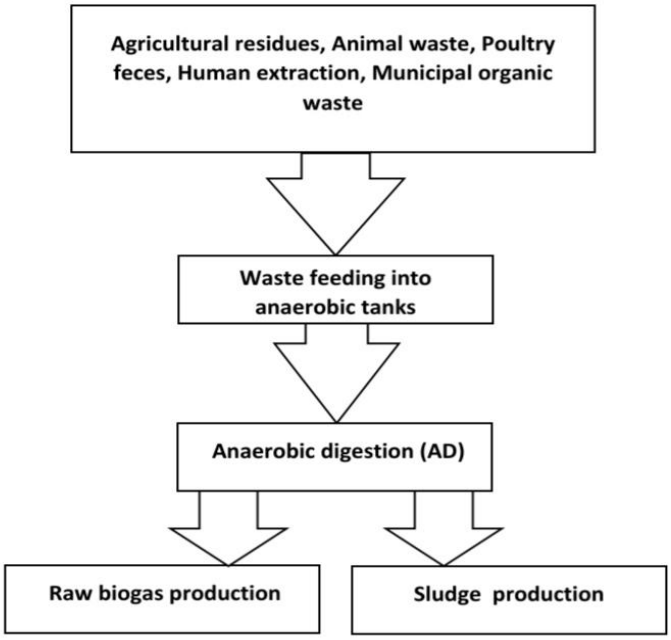

FIGURE 1: Outline of raw biogas production process

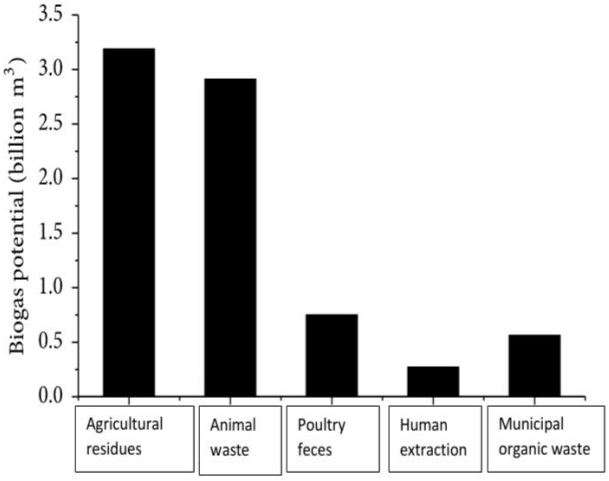

FIGURE 2: Biogas generation potential from different biomass wastes[4].

During anaerobic digestion (i.e. digestion in the absence of oxygen) [FIGURE 1] material is broken down in several steps by different types of microorganisms. The end-products are a gas containing mainly methane and carbon dioxide, referred to as raw biogas; and slurry or solid fraction consisting of what is left of the treated substrate, referred to as digestate. Raw biogas can be produced from most types of organic raw

material, except for lignin, which is not anaerobically degraded. The substrate composition will affect the yield of biogas and its content of methane. Landfill gas is produced during anaerobic digestion of organic materials in landfills and is very similar to biogas. Its methane content is generally lower than that of biogas, and landfill gas usually also contains nitrogen from air that seeps into the landfill gas during recovery. Landfill gas can also, in contrast to e.g. biogas from farms, contain a great number of trace gases.

3. Raw biogas composition

Parameter	Raw Bio gas
Methane (Vol. %)	50-70
Other Hydrocarbons (Vol. %)	0
Hydrogen (Vol. %)	0
Carbon-di-oxide (Vol. %)	30-50
Nitrogen (Vol. %)	0-1
Oxygen (Vol. %)	0-0.5
Hydrogen Sulphide (ppm)	0-4000
Ammonia (ppm)	0-100

TABLE 1: Composition of raw biogas[5]

4. Hazardous effects of contaminants present in raw biogas, when used as vehicle fuel[6]

(1) Carbon dioxide - (25-30% by volume):

(i) Lowers the calorific value

(ii) Increase anti-knock properties of engines

(iii) Causes corrosion in wet condition

(2) Hydrogen sulphide– (0-0.5% by volume):

(i) Causes corrosion in equipment and piping system

(ii) Leads to the emission of sulphur dioxide

(iii) Spoils catalyst

(3) Ammonia – (0-5% by volume):

(i) Causes NO_x emissions

(ii) Increases anti-knock properties of engines

(4) Water vapour –(1-5% by volume):

(i) Causes corrosion in equipment and piping system Due to condensation, it damages instrument and plant.

(ii) Poses risk of freezing of piping system and nozzles

(5) Dust– (>5µm): Blocks nozzles

(6) Nitrogen – (0.5% by volume):

(i) Lowers the calorific value

(ii) Increases anti-knock properties of engines

(7) Siloxane - (0-50 mg/m)[7]: Damages engines

5. Upgrading technologies for raw biogas, used as fuel for transport applications

The idea to power I.C. engines with gaseous fuels appeared first in the 19th century and was used in the first I.C. engine, constructed by Etienne Lenoir in 1860. Illumination gas was then used. The engine had the power of 12KM. In 1878, Nikolaus A. Otto and E. Langen constructed a four-stroke engine fuelled with gas. In 1896 in Dessau and in 1897 in Jelenia Góra, there were trams fuelled with illumination gas stored in three containers at 0.6 MPa. In 1918, natural gas was used for the first time to fuel a bus engine. In the 1930s in Italy, gas engines were used in vehicles on a bigger scale[9]. In the world, gas became more popular as engine fuel in the 1970s since there was an energetic crisis. In the recent years, the interest in biogas fuels has grown since conventional fuels are getting more and more expensive and the limits for toxic fumes emission are tighter and tighter.

The process of upgrading raw biogas generates new possibilities for its applicability at larger scale as then it can be used as a substitute to natural gas (TABLE 3). However, upgradation of biogas is a cost-investing process. When biogas is used for heating and electricity production, only water and H_2S removal is required. However, most of the gaseous impurities need to be removed for transportation fuel conversion. It is therefore important to have an optimized upgrading process (FIGURE 3) in terms of low energy consumption and high efficiency giving high methane content in the upgraded biogas. Also, the loss of methane with the reject gas during upgradation should be as low as possible[10]. Upgrading the raw biogas mainly comprises removal of carbon dioxide to increase its fuel value[11], this will result in an increased energy density since the concentration of methane is increased[5]. passing through the cleaning step involving the removal of hydro- gen sulfide and water[12]. The cleaning procedure is necessary in order to avoid operational problems in the upgrading procedure; however, being acidic in nature, trace of hydrogen sulfide and nitrogen can also be removed along with carbon dioxide[13].

Several technologies for raw biogas upgrading as vehicle fuels are commercially available and others are at the pilot or demonstration plant level. Some of these technologies are :

- Pressure Swing Adsorption (PSA);
- Water scrubbing;
- Organic physical scrubbing;
- Chemical scrubbing;
- Membranes.

It is important to remember that the best technology to choose is based on specific parameters at the plant, such as the availability of cheap heat and the electricity price. However, it should also be noted that it is often possible to lower the methane loss, but at the expense of a higher energy consumption.

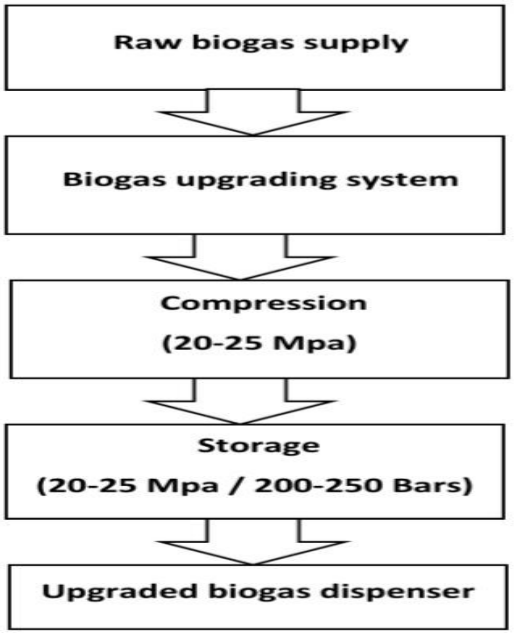

FIGURE3: A common outline of upgrading biogas technology.

Upgraded biogas, a methane rich compressed fuel, is also known as compressed biomethane/Bio-CNG. According to the way described above, Bio-CNG is produced from pure biogas containing more than 97% methane at a pressure of 20-25 MPa. It is very similar to the regular CNG in terms of its fuel properties, economy, engine performance, and emissions. Like regular CNG, bio-CNG has high octane number which results in the high thermal efficiency. The performance of a constant speed internal combustion engine using CNG and bio-CNG was compared and it was noted that their engine performances were almost similar in terms of brake power output, specific gas consumption, and thermal efficiency[14]. Bio-CNG can be injected into the CNG grid and blended with CNG. However, if the current CNG grid is inadequate, bio-CNG can be transported by trucks or in cylinder from the locations of production to the filling stations. From the literature, bio-CNG delivers greater environmental benefits than other traditional vehicle fuels as well as biodiesel and bioethanol[15]. Considering both technical and financial performance production of bio CNG for vehicle fuel is at least feasible as it is produced from renewable wastes. Therefore, the huge potentiality of different wastes in India can make bio-CNG production a viable option.

Parameter	Raw Bio gas
Methane (Vol. %)	92-98
Other Hydrocarbons (Vol. %)	0
Hydrogen (Vol. %)	0
Carbon-di-oxide (Vol.%)	10-15
Nitrogen (Vol.%)	0-1
Oxygen (Vol.%)	0-0.5
Hydrogen Sulphide (ppm)	0-100
Ammonia (ppm)	0-50

TABLE 2: Upgraded biogas / bio CNG composition

6. Vehicle technology requirement

The development of vehicle's power systems enabled to use upgraded biogasas fuel. It appears in the following versions:

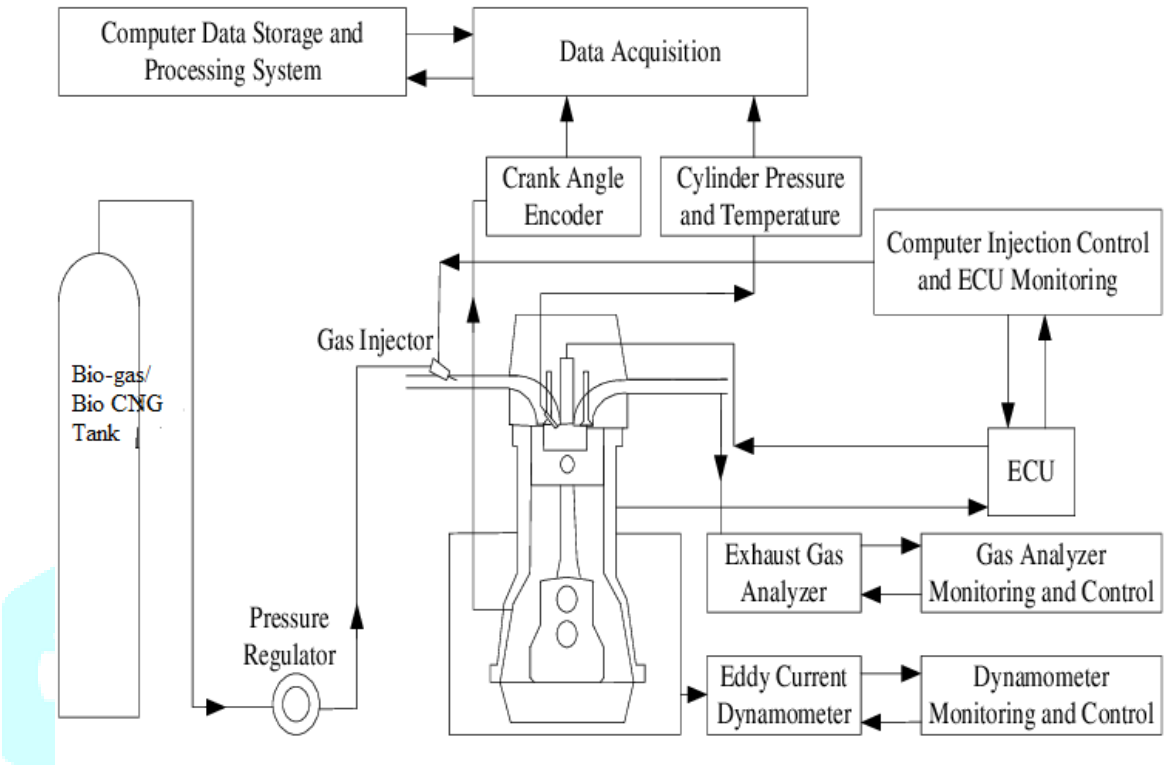

FIGURE 4: Outline of Upgraded biogas / bio-CNG fuelled vehicle technology requirement[16]

Upgraded biogas compressed to 200-250 bars in one - fuel S.I. engines, with modern solutions with multi - point injection. Upgraded biogas / bio-CNG is supplied from high pressure fuel tanks via a fuel filter and high Pressure regulator valve. The inlet filter is integrated into the high pressure regulator (FIGURE 4) . From the high pressure tank, fuel enters the high-pressure regulator where tank pressure is reduced to the appropriate working pressure to supply the fuel injectors in the Fuel Metering Valve (FMV). From the high-pressure regulator outlet, the fuel enters the low pressure fuel filter. Fuel is supplied to the FMV at a nominal pressure of 650 kPa gauge (95 psi gauge). Fuel is metered by the FMV to get the correct air/fuel ratio and is delivered to the mixer where it is mixed with air upstream of the throttle. By using Heated Exhaust Gas Oxygen (HEGO) sensors, the OH system provides precise control of air fuel ratio in order to assure optimal performance of the two way catalytic converter. The OH system controls air gas mixture via an electronic throttle assembly. This drive-by-wire throttle permits seamless integration of features such as pedal control, idle speed governing and maximum engine speed governing. The OH system provides accurate control of ignition dwell and spark timing under all speed and load conditions in order to assure desired torque with minimal emissions.

7. Conclusion

The feasibility of raw biogas conversion into transportation fuel primarily depends on some key factors such as economic, technical, environnmental, and safety. Fuel properties of upgraded biogas/ bio-CNG are nearly the same as regular CNG and also competitive compared to the other automobile fuels such as diesel and petrol. The percentage of methane (>97%) in bio-CNG is higher than that of natural gas (93%) produced from different gas fields in India. Besides this, the calorific value of bio-CNG is about 53 MJ/kg which is higher than the calorific value of petrol (47.8 MJ/kg) and diesel (44.6 MJ/kg)[4-6]. The amount of energy cost in kJ/BDT is almost 3.5 times that of petrol and 2.25 times of diesel[1-4].

The energy content of biogas and landfill gas is dependent on its content of methane. The energy content for biogas with a methane content of 65 %, and for biogas upgraded to 97% methane can be seen in the TABLE 3, as well as the energy content of some other fuels.

Fuels	Energy content [kWh]
1 Nm3 biogas (65% methane)	6.5
1 Nm3 biogas (97% methane)	9.7
1 litre petrol	9.1
1 litre diesel	9.8

TABLE 3: Energy content of biogas and some other fuels [5]

Upgraded biogas can be used in a number of applications including fuel for natural gas vehicles. The main environmental benefit is that fossil fuels like petrol and diesel can be replaced. Natural gas used as a vehicle fuel gives 20-30% lower CO2 emissions. For biogas the reduction of green house gas emissions can be as much as 100%. In fact, a reduction above 100% can be achieved when biogas produced from manure is utilized as a vehicle fuel. Methane, which is a strong green house gas, is released into the atmosphere from manure in traditional manure storage. Biogas as a vehicle fuel can thus both decrease the leakage of methane from manure and decrease the emissions of fossil carbon dioxide. Another advantage is that vehicles running on upgraded biogas/ bio CNG have lower emission of particles, NO_x and SO_x.

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