

DESIGN AND ANALYSIS OF BIOGAS DIGESTER: A REVIEW

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Abstract - This paper reviews the main technical, operational and economical aspects of a biogas plant. The analysis is focused on the key points of the biogas production process, the current situation of biogas plants in Europe and the advantages, risks and new trends of the production and use of biogas. The paper offers an integrated view of the different aspects involved in a biogas plant as source of renewable energy in contrast with other more analyzed renewable energy sources based mainly on wind or solar energy.

Keywords- biogas; biogas plant; organic matter; green energy production; combined-heat and power system

1. INTRODUCTION

Nowadays, renewable energy production is an extremely important topic in many interconnected fields such as research, energy production, social acceptance, reduction of the use of non-renewable sources of energy, government strategies, etc. A great deal of effort is being made to use energy coming from renewable energy sources. The renewable energies which are most frequently used in the world are wind and solar, and in particular, energy coming from the wind is the most extended. Other renewable sources of energy are being used in well-known operative technical processes but for different reasons they are not as extended as those previously mentioned, such as for example, the industrial biogas plants. This paper reviews the key aspects of biogas production in an industrial biogas plant in order to obtain an integrated picture about their advantages and disadvantages at present. In particular, the current situation of such plants in Europe will be considered. The paper is organized around the following sections. Section II describes the biogas production, its requirements, technology and use of the biogas obtained. Section III analyzes the basic economics of a biogas plant. Section IV describes the experience of the biogas plants throughout Europe. Section V includes the conclusions and key points of the industrial biogas plants.

2. BIOGAS PRODUCTION:

What is biogas? How is it produced? Biogas is a mixture of mainly methane gas (CH₄) and carbon dioxide gas (CO₂). If this is compared with natural gas, in which the methane content is about 90-95%, it is possible to conclude that biogas is a low grade natural gas. As a consequence of the previous assertion, the energetic potential of biogas is much lower than that of natural gas. Four essential ingredients are required for the production of biogas (H. House, 2007) [1], [2]: organic matter coming from any organic source, bacteria, anaerobic conditions and heat. The process of biogas production requires a large amount of microorganisms, (bacteria), which are able to use the stored energy in carbon hydrates, fats and proteins under anaerobic conditions for their metabolism. Bacteria use the organic matter as a food source for producing methane by the decomposition of organic matter. There are many different types of sources of organic matter that can be used for biogas production. Essentially the more commonly used are manure coming from farm animals, wasted food, wastewater, wood and agricultural products such as corn silage. The amount of potential biogas produced depends on the amount of dry organic matter contained in the feedstock used. Different types of organic matter can be mixed together for biogas generation in an industrial biogas plant. Energy crops have higher contents of dry matter [3] and for this reason they have been a target source in biogas production by industrial plants over the last years. In particular, the dry organic matter content of corn silage, one of the most frequently used agricultural substrate, consists of around 35% of the total volume. The second ingredient needed for biogas production is bacteria, which are needed in order to convert the fats, carbohydrates and proteins contained in the organic matter to simple acids such as acetic and propionic acid. Then, a second type of bacteria transforms the acids to methane and carbon dioxide. These processes occur simultaneously. The bacteria are commonly present in manure, in wasted food or wastewater and in agricultural produce harvested with green parts such as corn silage or similar green plants. In order to fulfil the expected function of the bacteria in the production of biogas, two key conditions are necessary: an anaerobic atmosphere (without oxygen) and heat. The temperature has to be in the range 35-40°C (within the mesophyll range of operation, this is typical), or between 55- 60°C

(thermophiles range). The pH-value should be neutral up to a low alkaline value.

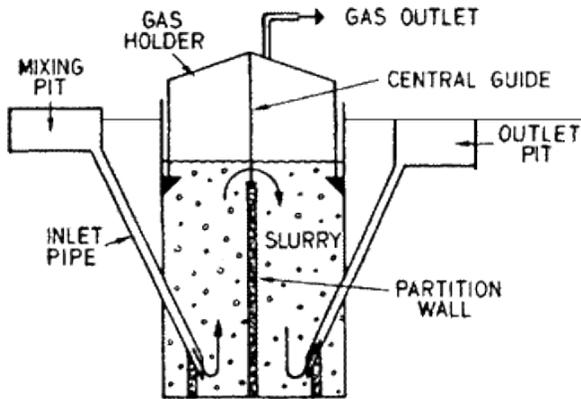


Fig1. Construction of Bio Gas plant (Ref.by-[13] Bhat, P.R., Chanakya)

3. Biogas uses:

The produced biogas can be used in many ways (combustion for the production of electricity and heat, to be fed into a gas grid, in fuel cells or even as fuel) [10], [11]. The most common alternative is the utilization in a gas engine for the production of electricity and heat. The produced electricity can be fed into the public electricity grid, receiving funded tariffs for it. In order to optimize the utilization of the produced biogas and to maximize the profit of the plant, the utilization of the excess of heat from the combustion of the gas should be considered. This heat can be used as process heat for the digestion process or for heating parts of the plant or adjacent agricultural buildings (e.g. stables). The best option for using the excess of heat is to sell it to an external heat consumer [7], [12], [13]. The typical use of biogas in a gas engine is based on a cogeneration system or a Combined Heat & Power System (CHP). In order to use the biogas as input in a gas engine, its impurities have to be removed. Particularly it is important to remove the hydrogen sulphide (H₂S) contained in the biogas. The limits for H₂S for biogas used in gas engines lie between 100 and 500 ppm, depending on the manufacturer. The lower the amount of H₂S, the higher is the lifespan of the gas engine. In addition to the desulphurization, it is also necessary to dry up the biogas. Biogas is very attractive due to its versatility of use in different markets such as electricity, heat, vehicle fuels and reuse in agriculture. In fact biogas can be used for:

- Production of electricity and heat (cogeneration)
- Production of electricity alone
- Production of heat alone
- Upgrading to bio methane for: injection in the gas grid, transportation fuel, high tech process energy, raw material for the chemical industry

The main advantage of biogas is

the production of green energy, but this is not the only advantage. Biogas has other advantages for the producer and for society. If biogas is produced using waste raw material such as manure, wasted food or waste water, the production of biogas contributes to the reduction of pathogens and odor that can cause health problems, or at the very least, mitigate an uncomfortable environment [14]. In general, the use of biogas as an energy source is widely considered as CO₂ neutral because the CO₂ released during combustion of the biogas is almost the same CO₂ that was assimilated during photosynthesis to create organic matter in energy crops. In this way the burning of biogas is simply a recycling of CO₂ in the biosphere [15]. However in addition to this, the energy production itself also helps to reduce the emission of greenhouse gases; its magnitude depends on which fuel is being replaced. If biogas replaces oil, less oil will be used and there will be a reduction in emissions.

4. Literature Review:

Govt. of India's report(2002) on –Evaluation Study On National Project on Biogas Development||, presents a preliminary study of two highly successful rural biogas models wherein biogas is produced and utilized as a cooking fuel by the villagers. The two models studied were the Community Biogas plant established by SUMUL Dairy at Bhintbudrak, Gujarat and the Individual Biogas plants established by BhagirathPratisthan (an NGO) in south Konkan region of Maharashtra. Various aspects including design, operation, economics and benefits to the stakeholders had been described. The report ends with a comparison of the two models studied on the basis of their design, vision, performance, economics and benefits. Sagagi, et al. (2009) presented results of the study on biogas production from fruits and vegetables waste materials and their effect on plants when used as fertilizer (Using digested and undigested sludge). It has been observed that the highest weekly individual production rate is recorded for the cow dung (control) slurry with average production of 1554 cm³ of biogas, followed by pineapple waste which had 965 cm³ of biogas, then by orange waste which had 612cm³ of biogas, lastly, pumpkin and spinach wastes had 373 cm³ and 269 cm³ respectively. The results obtained shows that difference in the production of biogas to a large extent depends on the nature of the substrate. All the substrates used appeared to be good materials for biogas production and their spent slurries can be used as a source of plant nutrients. ReinhardMadlenera, et al. (2006) compares multi-criteria decision aiding (MCDA) and data envelopment analysis (DEA) approaches for assessing renewable energy plants, in order to determine their performance in terms of economic, environmental, and social criteria and indicators. The case is for a dataset of 41

agricultural biogas plants in Austria using anaerobic digestion. The results indicate that MCDA constitutes an insightful approach, to be used alternatively or in a complementary way to DEA, namely in situations requiring a meaningful expression of managerial preferences regarding the relative importance of evaluation aspects to be considered in performance assessment.

5. BIOGAS BASIC ECONOMICS:

While there is no question about the technical feasibility of an industrial biogas plant, its economic feasibility is always a point of important concern that must be carefully analyze

It is difficult to issue a general rule valid for any type and configuration of biogas plants, but under the more extended scheme of the use of biogas for electricity production, the investment required for building and maintaining an industrial biogas plant in production, hardly compensates for the revenues coming from selling the electricity produced. A simple example with real values is presented as an illustration of this assertion. The results in this example where obtained using the worksheet [19] and simplifying the information resulting from it. In the case that there is cattle manure available that can be mixed with the corn silage into the digester, the potential production of biogas is presented. According to the information included, and considering typical ratios of a CHP system performance, the expected results of the plant for this case example are included in Table III. An average period of operation of 8000 hours per year and an average price for selling electricity of 0.035 € As it can be observed, an important amount of heat is being generated from which the possible revenue from selling it was not considered. This is one of the worse scenarios where the heat cannot be reused. Also revenues from products resulting from the digestion of the organic matter, mainly compost that can be used as fertilizer, were not taken into account. In our example the main costs are coming from the initial investment for building and starting the biogas plant, its maintenance and the cost of the raw materials required as inputs for the plant. The cost of the required animal manure normally is reduced to the cost of transport from the farm to the plant and in some cases it does not exist due to the proximity or agreements between the parts. In the case of the use of corn silage as raw material in the biogas plant, as was considered in the example, its cost has to be taken into account. Once again the price will depend on the type of agreements established between farmers and the biogas plant. Very often the farmers are also stakeholders of the plant and the prices could be different if there is a long time guarantee

for them that the whole production of corn is acquired by the plant. References [20], [21], [22] evaluate prices for corn silage between 21 and 36 € per tonne of which the range is due to different reasons such as variability of the prices of corn grain, seasonal factors and type of selected hybrid.



FIG.2 Proposed set up of biogas digester

6. Conclusions:

The key conclusions of the paper are: 1) several financial and nonfinancial barriers exist resulting in the low penetration of biogas technology in India 2) barriers vary strongly between biogas system in urban and rural areas due to difference in technology maturity, feedstock availability and quality, supply chain, awareness level and policy support; Another key contribution of the paper is the identification of key areas of improvements in existing policies as well as strategies to overcome the existing barriers.

Based on our findings, several policy recommendations are drawn for overcoming these barriers. The greater need for clean and affordable energy in rural areas is for the overwhelming population belonging to low and middle-income rural households. The key barrier to the deployment of the rural biogas plants among these households is the upfront installation cost of the biogas plant. Presently, under the NBMMP, the financial incentive for installing biogas plant is targeting the households having adequate cattle ownership. Such a categorization excludes a sizable fraction of the middle and lower-income rural households. A bottom-up approach should be adopted to increase the dissemination of biogas in rural areas. The socio-economic characteristics like household size & income, agro-climatic conditions should also be considered while developing policies for biogas dissemination in rural areas.

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