Generating Biogas to Achieve Sustainable Development of Waste Management

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Abstract

The growing trend of energy consumption has resulted in energy crisis in the world. In addition, widespread use of fossil fuel has caused emission of a large amount of pollutants, hence the global environmental crisis. On the other hand, limited resources of fossil fuels, non-renewability of these resources, price volatility of fossil resources, and protecting the environment against the pollutants have brought about policies to change the energy carriers and moving toward clean fuels as a top priority in many countries' working plan around the word. Optimizing energy consumption, reforming it, managing waste of human activities, and protecting the environment are the main elements of sustainable development. One of these options which leads to development and sustainability in the field of energy, agriculture, and environment, is using the energy of biomass. During the recent years, a lot of attention has been drawn to biomass generation to supply the energy in the world, particularly by the developed countries. This produced gas can be used to supply thermal energy, light, and also as a proper choice in internal combustion generators, microturbines, fuel cells, and also electricity generation. In this research, the importance of this biological energy source in supplying the required energy, resolving the problems due to lack of proper management of swage collection and disposal in order to reach sustainable development have been discussed.

Key words: energy crisis, managing waste, sustainable development, biomass generation

1. Introduction

The growing rate of energy consumption over the recent years has lead to a global energy crisis and the non-renewable resources will disappear if this trend does not change. Due to the pollutants caused by them, mankind's health is in serious danger. On the other hand, nowadays one of the issues related to the growing population of the world is the waste materials produced. Solutions must be found to this problem so that while disposing the waste materials, the environment is not harmed. Biological refinement is the best option to refine organic material with low calorie content in solid waste. One of the methods of biological refinement is anaerobic digestion. Nowadays anaerobic digestion of biomass is regarded as an energy generative technology. Anaerobic digestion of the organic part of solid waste is an almost new phenomenon, and its advantages outweigh those of other options of solid waste disposal. Some advantages are the energy generation, building a healthy environment, and rich fertilizer production. Sustainable development based on the three principles social sustainability, economic sustainability, and environmental sustainability has offered some solutions against unsustainable patterns of physical and economic development and to prevent the environment and the biological systems from getting damaged, the climate from getting changed, the earth from getting over-populated, and the quality of life from declining and also to prevent injustice, so that while the needs of today's mankind is satisfied, future generations will life in at least the same world [1]. Policies and plans have been made to reach the sustainable development based on sustainable development principle. One of these options is using the energy of biogas. Considering the desired style of energy, nowadays discovering new renewable energy resources is vital [2]. Furthermore, the growing amount of organic solid waste is one of issues of human society. Regarding the sustainable development, managing degradable waste, and discovering new renewable energy resources, and producing biogas from degradable organic waste are convenient options. Biogas is the sum of gases generated by degradation and fermentation of animal, human, and plant waste due to absence of oxygen and activity of anaerobic bacteria. Among the renewable energy resources, biomass energy has made up 79.7% of the world total consumption and the countries which generate energy from biomass sources are: America, Brazil, Philippines, Germany, Sweden, and Finland [3].

2- The necessity of using biogas in Iran:

The growth in population and production of waste material such as human and animal excretion, home garbage, and unwanted materials form food and agricultural industries have lead to widespread water, soil, and air pollutions and pollution in biological systems. To reach sustainable development of waste management, constructing biogas installations in addition to remarkable economic and social impacts can solve the issues mentioned above and help to save the valuable fossil fuel resources. Although using biomass energy is not economical while fossil energy resources exist, limitations of fossil fuel and price volatility in the world markets and also expansion of using renewable energies highlights the importance of these resources. Generating energy from rubbish has a lot of advantages; gathering biogas from landfills is one of most important issues in waste management since methane is one of the main greenhouse gases leading to global warming whose impact on global warming is much stronger than that of carbon dioxide. By establishing biogas units, the disposal of waste in landfills can be reduced and prevent accumulation of methane which causes fire and explosion. In addition, along the positive environmental impacts, the income obtained by generating electricity and heat in this way is significant. The amount of energy generated from biomass in Iran will be 16146.35 m^3 (9175 x 10^6 m^3 of methane) of biogas annually which is of the value of 30367 x 10^{17} J energy and it is not reasonable to ignore this clean energy. Iran produces 15 million tons of urban waste and 4.6 billion m^3 of urban and industrial swage and biogas technology can be an important potential in waste management to produce clean energy.

3- Introducing biogas:

Biogas is obtained by applying a set of physical, chemical, and environmental processes such as degradation, and fermentation on various biomass like unstable organic excretion and waste of human, animal and plants, in the absence of oxygen and by the activities of anaerobic bacteria in fermentation container which consists of 40-60 % of methane (usually 55-65 %), carbon dioxide, and a small proportion of other gases [5] which after a series of refinement processes according to global and environmental standards and on this gas, it can be considered a clean fuel which can be used directly and without removing carbon dioxide, or by applying suitable generators it can be changed to electricity. Fig. 1 shows the chemical composition of biogas.

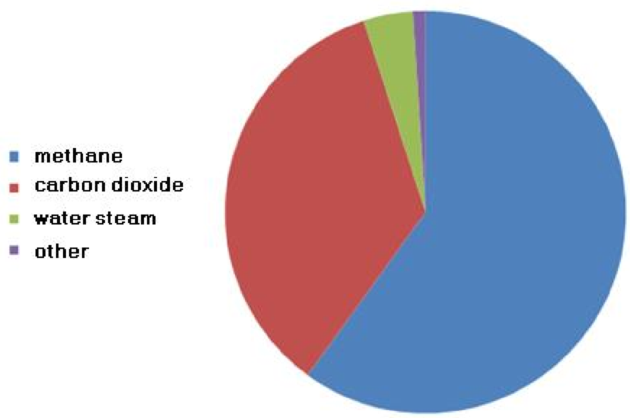

Fig. 1 shows the chemical composition of biogas

Biogas production steps are:

1. Large macromolecules such as protein, fats, and carbohydrates polymers (cellulose, starch) break into amino acids, long chain fatty acid and sugars through hydrolysis process.
2. While forming acid, these products ferment to make volatile fatty acids, butyric, propionic, mainly lactic and valeric acid.
3. In acetogenesis, bacteria use these fermentation products and produce lactic acid, carbon dioxide and hydrogen.
4. methanogenic organisms use acetate, hydrogen, and some amount of carbon dioxide to produce methane.

Three biochemical paths which are used to produce methane by methanogens are:

1) acetotrophic path, 2) Hydrogenotrophic path, and 3) Methylotrophic path

Theoretically, biogases must contain equal volumes of methane and carbon dioxide. Anyway, acetogenesis typically produces some hydrogen and for each 4 moles used by hydrotrophic methanogens, one mole of carbon dioxide changes to methane. Fats and proteins cause more production of hydrogen and this greater efficiency, leads to a higher content of ordinary methane for these materials. In and stable condition, these molecules can also change into other methane products. Therefore, in general biogas efficiency and methane content for different materials and under different conditions of digest and bacteria group are different [5]. Different steps of chemical fermentation (break of the original organic material by bacteria) are shown in fig. 2.

Three physiological bacteria involved in anaerobic transformations of organic materials are:

1. The first group, hydrolysis and fermentation bacteria: this group change complex organic material like carbohydrates, proteins, and lipids to fatty acids, alcohols, carbon dioxide, ammonia, and hydrogen.
2. The second group, change the products of the first group to hydrogen, carbon dioxide, and acetic acid.
3. The third group consists of two different physiological groups of bacteria forming methane one of which changes hydrogen and carbon dioxide into methane and the other produces methane from decarboxylation acetate [6-8].

Biogas, a clean gas which is flammable and lighter than air, is a kind of fuel. The sources of bomass from which biogas can be produces are [9]: 1. Waste from agriculture and related industries, 2. Solid municipal waste, 3. Municipal wastewater, 4. Animal waste, 5. Corruptible Industrial solid and liquid waste (industrial sludge). The specifications of the components of biogas can be seen in table 1. By compressing the methane in biogas, it can be used as a municipal gas supply, domestic fuel for cooking and heating purposes. It can also be used as CNG fuel in natural gas vehicles and to produce electricity as well. Using biogas in transportation industry reduces 65-85% of carbon dioxide which increases greenhouse gases [10]. In table 2 the specifications of ordinary gases have been compared with those of biogas. Since this process takes place by contribution of microorganisms and depends on different factors such as pH, temperature, time, and hydraulic retention time (HRT), it is a relatively slow process. On the other hand, lack of stability, low loading rate, slowing the speed of improvement after degradation and break, and specific requirements to combine garbage, are some of the other drawbacks of this process [11].

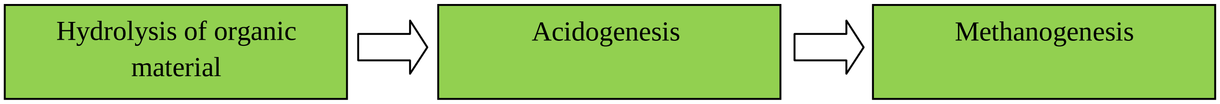

Fig. 2 The chemical process of fermentation

Table 1. Biogas components

Gas	Formulation	Percentage
Methane	CH_4	55-65
Carbon dioxide	CO_2	35-45
Nitrogen	N_2	0-3
Hydrogen	H_2	0-1
Oxygen	O_2	0-1
Hydrogen Sulfide	H_2S	0-1

Table 2. Comparing the characteristics of typical gases with those of biogas [2]

Gas	Required Air M^3	Pressure speed in air	Specific weight in relation with air	Calorific value	Components (100%)	Composing chemical elements
Methane	9.5	43	55	9.94	100	CH_4
Propane	23.8	57	1.56	25.94	100	C_3H_8
Butane	3.9	45	2.07	34.02	100	C_4H_{10}
Natural Gas	7	60	38	7.52	65, 35	CH_4, H_2
City Gas	3.7	82	41	4.07	50, 26, 24	CH_4, O_2, N_2
Biogas	5.7	40	94	5.96	60, 40	CH_4, CO_2

Various methods are employed to improve the general efficiency of anaerobic digestion some of which are as following:

- Various optimizations of functional parameters;
- Satisfying the requirements of feeding microbes using biological differences;
- Chemical additives;
- Modifying the feed ration; and
- Modifying and changing the design of the available biogas device

Moreover, recently efforts have been made to reduce HRT, or to increase the generated biogas from the same HRT by mixing the constant microbe layer in the reactor (which is done preserve the microbes in the reactor) [14]. For anaerobic fermentation in order to produce biogas a couple of conditions must be met some of which are:

- The environment must be anaerobic.
- The temperature must be between 30 ^{oC} to 55 ^{oC}.
- A mixer must be used to homogenize and stimulate the bacteria within the digestion container.
- The system feed must be dry organic up to 7 – 9 %.
- pH of the environment must be between 6.5 – 8.
- The input raw materials must be of much variety.
- The presence of deterrents such as heavy metal salts, antibiotics, and disinfectants must be prevented.
- Gas production accelerative material must be added to the digestion container.
- Minerals such as Nickel and Molybdenum must be used to advance the reaction better.
- The Carbon to Nitrogen ratio (C/N) for the activity of the anaerobic bacteria must be 30 – 35 [2].

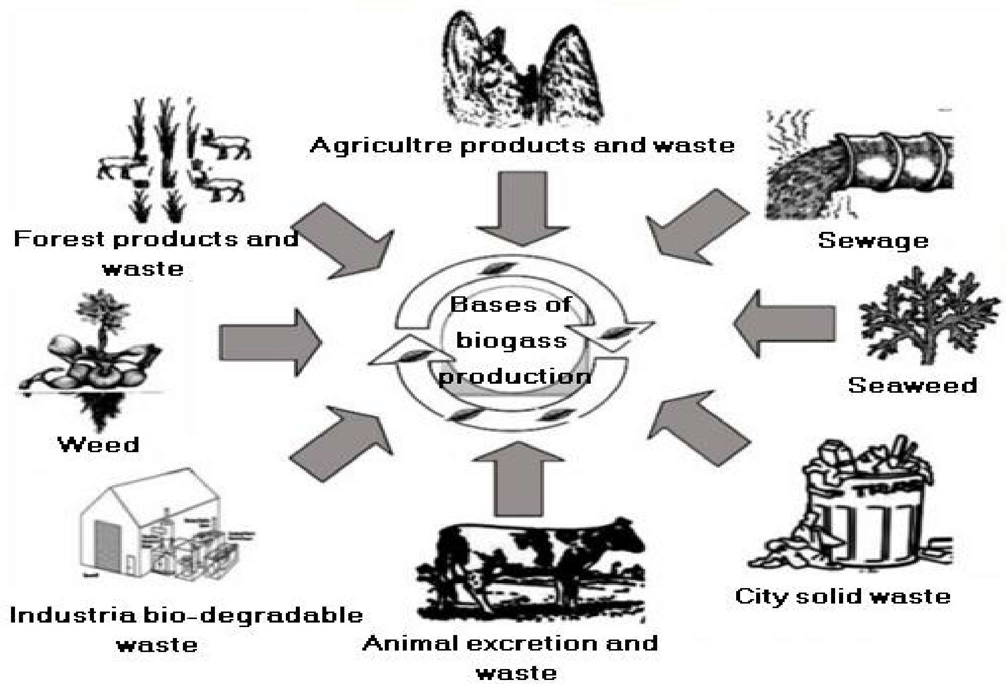

Fig. 3. Resource for anaerobic fermentation to produce biogas

4. The fundamentals of a biogas device

All such devices consist of a inlet pool, anaerobic fermentation container, outlet pool, biogas gathering container and transmission and employing biogas system. Fig. 4 shows the components of a biogas device [1].

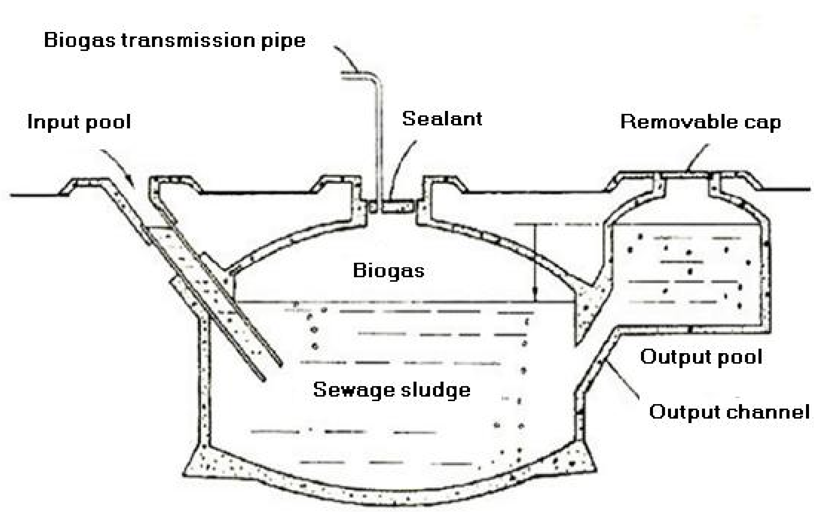

Fig. 4. The components of a biogas generator device [1]

Organic waste are mixed with water and are sent to the lower fermentation container through the inlet pool which is build on the upper surface of the ground. By setting suitable condition in terms of temperature, humidity, and absence of oxygen, the fermentation container maximizes the production of biogas resulted from anaerobic fermentation. After fermentation and producing gas, and after adding some new material, mixture is sent to the outlet pool (compost pool) through special channels. The gas container is located above the fermentation container where the gas is gathered and stored. After starting, the produced biogas is sent to the place of use through a special valve which is located at the top of container [2 and 15]. The best model of biogas device is the one whose walls are made of brick and other local materials of Iran and whose structure is mainly under the ground. The advantages of such a device are low construction cost and simple maintenance. This model is known as the Chinese model in the world [2]. Fig. 5 shows the structure of the Chinese model.

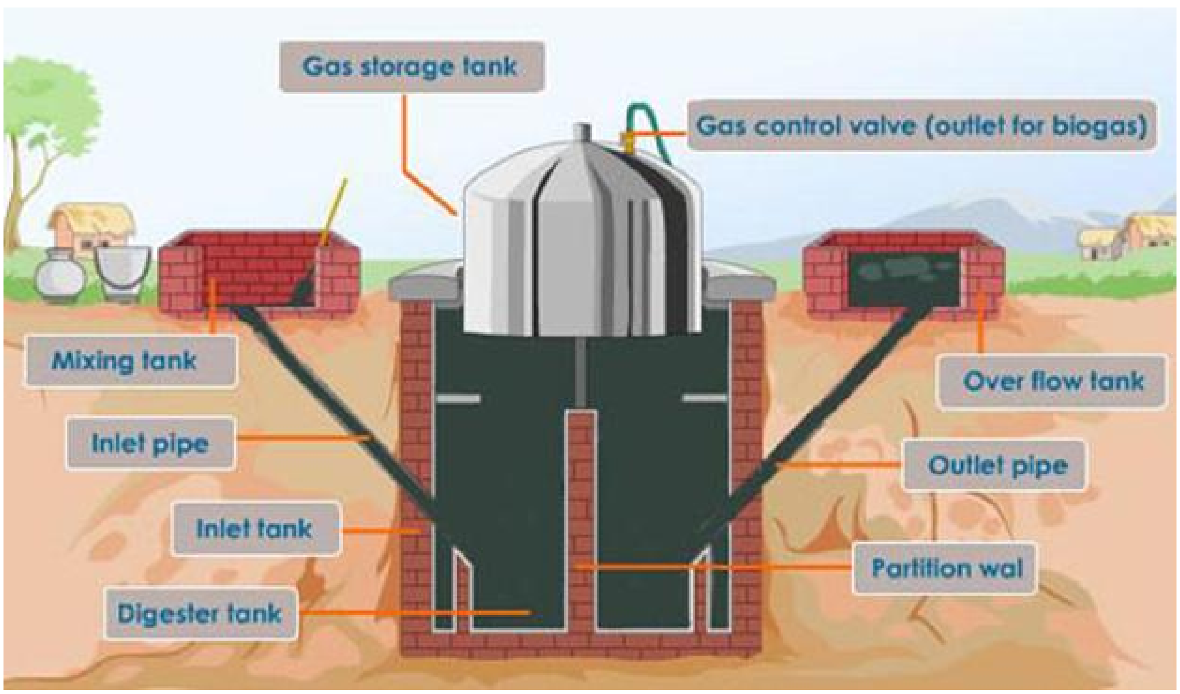

Fig. 5 the structure of the Chinese model.

5. Advantages of producing biogas

- Producing methane and carbon dioxide by anaerobic degradation of organic materials, as the primary industrial material (methane can be used as the primary material to produce acetylene, alcohol such as methanol, ammonia, fertilizer, and even vitamin B_{12}, and carbon dioxide can be used to produce fertilizer and dry ice.
- The wastewater from digestion containers is a suitable substitution for chemical fertilizers. The fertilizer obtained in this way does not have any negative impacts on the environment (without smoke, and odor). The quality and quantity of nitrogen in the fertilizer produced in this way is better and richer than typical fertilizers.
- Biogas installations preserve pastures and forests. It also saves fuels such as wood, coal, and oil and changes the plant and animal waste to organic fertilizers and eliminates the contaminations of them.
- The gas from the installations provides households' lighting and fuel.
- These installations are capable of providing energy for impassable villages out of energy networks.
- This method is a suitable alternative to energy generative fuels and the contaminations resulted from burning them is by far lower than fossil fuels.
- Optimizing rural areas of villages, cities, and natural bedrocks which are landfills of garbage and wastewater.
- This method prevents greenhouse gases from increasing and hence prevents global warming and severe climate changes.
- Provides and income by selling energy, organic fertilizer and water usable in agriculture.
- Prevents landfills from expanding and hence reducing the related costs.
- Blocking the outflow of currency due to production of organic fertilizer and reducing the consumption of chemical fertilizer and hence reducing the demand for pesticides, weeds, and fossil fuels;
- Optimizing the conditions of cities and villages;
- Optimizing the condition of agriculture because of local access to rich organic fertilizer which is free of pathogens [16-18].

6. Applications and usages of biogas

Applications and usages of biogas in different fields in the form of energy and primary material in different industries are shown in fig. 6 [19].

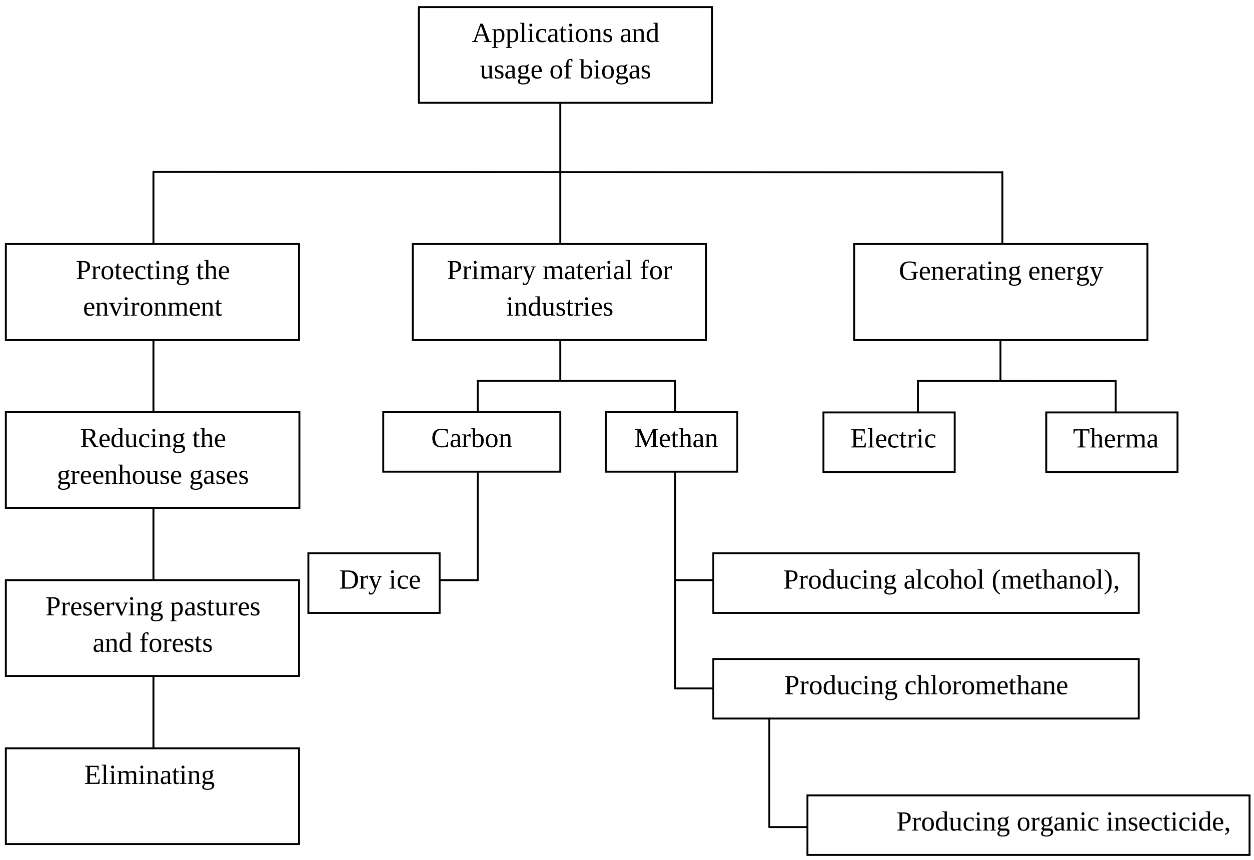

Fig. 6. Applications and usages of biogas

7- Conclusions

Nowadays, due to the limitations of fossil resources, resulted pollutions, and price volatility in the market, using renewable resources is vital. One of the dimensions in sustainable development is employing renewable resources of energy such as solar energy, wind, geothermal, biomass, and hydrogen. On the other hand, the growing population has caused widespread organic waste materials which not only lead to disgusting scenery, but also extended pollutions of water, soil, and air resources. In order to achieve sustainable development management and by constructing biogas units, a remarkable amount of electricity and heat as well as thousands of tons of natural fertilizer for agriculture purposes can be produced and help to save valuable fossil fuel resources. Furthermore, by developing biogas production units, in addition to positive social and economic impacts, problems such as water, soil, and air pollutions will decrease remarkably. Reducing the negative effects of fossil fuels on environment, reducing nitrogen oxides, producing heat and electricity without negative environment effects, preventing landfills from expansion, reducing the demands for chemical fertilizers, producing methane, and carbon dioxide as the primary industrial material, soil enrichment as a result of using organic fertilizer, and finally, improving soil structure in the long term are to mention but a few of these valuable environmental outcomes.

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