

Studying the Environmental Effects of using Biogas Energy in Iran

Kambiz Tahvildari, Shakila Motamedi

Abstract—Presently and in line with the United Nations (EPA), human thinking system has shifted towards clean fuels so as to maintain a cleaner environment and to save our planet earth.

One of the most successful studies in order to achieve new energies includes the use of animal wastes and their organic residues, and the result of these researches has been represented in the form of very simple and cheap methods called biogas technology. Biogas technology has developed a lot in the recent decades; its reason is the high cost of fossil fuels and the greater attention of countries to the environmental pollutions due to the consumption of this kind of fuels.

IRAN is ready for the optimized application of renewable energies, having much enriched resources of this kind of energies; so a special place could be considered for it when making programs. The purpose of biogas technology is the recovery of energy and finally the protection of the environment, which is much appropriate for the third world farmers with respect to their technical abilities and economic potentials. Studies show that the production and consumption of biogas is appropriate and economic in IRAN, because of the high amount of waste in the agriculture sector, the significant amount of animal and human excrement production, the great volume of garbage produced and the most important the specific social, climatic and agricultural conditions in IRAN, in order to proceed towards the reduction of pollution due to the use of fossil fuels.

Keywords—Agriculture, Biogas, Energy, Environment.

I. INTRODUCTION

TODAY, mankind is facing as once did the mythological Orestes the harassment of three Furies or Erenias: hunger, the lack of energy and the deterioration of the environment. The point is that it is mandatory to defeat all these three Furies simultaneously, because any one of them, by itself, is able to wipe out our civilization. Today, for the first time in history, the human race may be the victim of its own genius. Today, for the first time in history, the human race may be the victim of its own genius [1]. Talking about energy, when we think about the whole problem, it is evident to everyone that saving it is the strategic approach to be privileged by reducing the enormous and irrational levels of consumption and increasing the efficiency of the use of conventional fuels, because it gives the best cost/benefit relation; but it is important not to forget the need to find new fuel sources. Fossil fuels account for over 80.3% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector [2]. This way, it is possible to conclude that fossil fuels are responsible for the emission of a significant amount of pollutants in the atmosphere, including greenhouse gases

(GHG). The intensive and low-efficient use of fossil fuels for supplying humans' energy needs over the past century reduced its reserves considerably, resulting in the prognosis of its exhaustion within the next decades. This phenomenon, known as 'Peak-Oil', will probably be characterized by the reduction in the world's oil production that may already start in 2010. This situation is causing a rise in the prices, bellicose conflicts, making some governments considerably concerned towards assuring their energy security. There is a unanimous opinion that says that the era of cheap energy is long gone. Climatic changes, as a result of global warming caused by greenhouse gases, mainly carbon dioxide (CO₂) produced during the burning of fossil fuels, have been causing significant changes in the ecosystems and leading to nearly 150,000 additional deaths every year [3]. The constant rise in Earth's average temperature, threatens millions of people with the growing risk of hunger, floods, water shortage and diseases such as malaria. Taking the aforementioned problems into account, the use of biomass, particularly biofuels, for energy purposes becomes increasingly interesting [1].

The term biofuel is referred to as solid (bio-char), liquid (ethanol, vegetable oil and biodiesel) or gaseous (biogas, biosyngas and biohydrogen) fuels that are predominantly produced from biomass [4]–[5].

Biogas (Marsh Gas) is a mixture of gases, produced by the decomposition and fermentation of animal and human excrement, plant residues (plants' branches and leaves) and agricultural products' residues which is made, as a result of the lack of oxygen and the activity of anaerobic bacteria. This is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO₂) and low amount of other gases as shown in Table 1.

TABLE I
COMPOSITION OF BIOGAS

| Substances | Symbo l | Percentage |
|-------------------|-----------------|------------|
| Methane | CH ₄ | 50 - 70 |
| Carbon Dioxide | CO ₂ | 30 - 40 |
| Hydrogen | H ₂ | 5 - 10 |
| Nitrogen | N ₂ | 1 - 2 |

| | | |
|-------------------------|------------------|--------|
| Water vapour | H ₂ O | 0.3 |
| Hydrogen Sulphide | H ₂ S | Traces |
| Source: Yadav and Hesse | | |

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 degrees to 750 degrees C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas [6].

Its calorific value is 20 Mega Joules (MJ) per m₃ and burns with 60 percent efficiency in a conventional biogas stove.

A- CLIMATIC CHANGES

Climate changes take place as a result of the intrinsic variability of climatic systems and of the action of external factors, either natural or anthropogenic. The emissions of greenhouse gases tend to elevate the temperature of the planet excessively. The temperature rise reached 0.6% with forecasts ranging from 2 to 4 8C by the end of this century. The report of the 4th Intergovernmental Panel on Climate Change—IPCC recognizes as highly confidence that the global warming is the net result of human activities [7]. One of the most important greenhouse gases is the CO₂. Over the past century, the atmospheric concentration of CO₂ reached its highest levels, as it is possible to be observed in Fig. 1 [8]. Since the pre-industrial times, the atmospheric concentrations of greenhouse gases have been increasing as a consequence, which has been just recognized, of human activities. This rise is mainly caused by the unsustainable use of fossil fuels and the changes in the use of the land (IPCC [9]). The expected variation regarding the climate includes changes in the intensity and in the distribution of rainfall, the elevation of the level of the oceans and a growing increase in the frequency and intensity of extreme climatic phenomena. According to IPCC [10] the biofuel demand for the transport sector in 2030 is forecast to be 45–85 EJ, based on primary biomass, or 30–50 EJ based on fuels. The same source indicates a global potential regarding the energy supply of biomass of 125–760 EJ in the year of 2050. This makes the energy use of biomass, in its different variants, a subject to be considered as an important element towards the mitigation of the greenhouse effect [1].

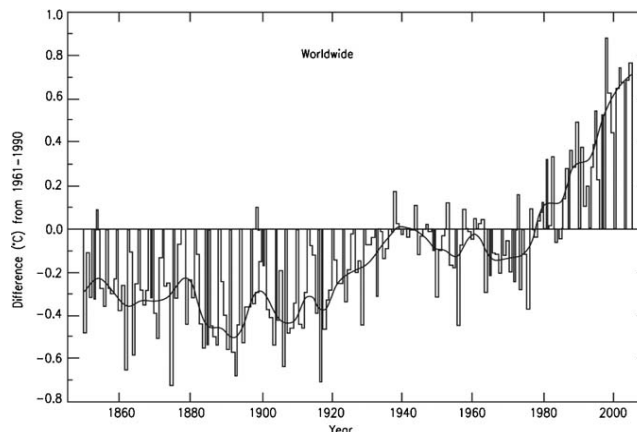


Fig. 1 Variations in the concentration of CO₂ in the atmosphere and the rise in the planet's global temperature [7].

Biogas could be used as an energy resource which is prepared easily. The heat value of biogas is mostly related to methane gas which burning each cubic meter of it produces 1.25 kilowatt electricity without spreading any amount and fumes. In general, the thermal energy of 1 cubic meter biogas equals 0.4 kilogram diesel fuel, 0.66 kg oil or 0.8 kg coal.

Biogas technology has developed a lot in the recent decades; its reason is the high cost of fossil fuels and the greater attention of countries to the environmental pollutions due to the consumption of this kind of fuels. Biogas is a kind of clean and renewable energy whose installations could be used especially in rural areas where the air's temperature is not very low (at the temperatures less than 8°C, no gas is practically produced) and in this way hygienic fertilizer with high quality and valuable for farms, specially for the cultivation of edible fungi, is made. This fertilizer which is in fact the deposited mud from the fermentation in the digestive tract of biogas is free of the weeds' seeds and parasites. The thermal energy of biogas is by far more than the heat obtained from burning dried animal excrement which is usual in some village and leads to air pollution. Besides the utilization of fuel and fertilizer in the biogas process, it is possible to separate methane and carbon dioxide gases from the biogas by polymer technology and produce dry ice from the carbon dioxide.

Dry ice is a good drying substance which creates cold three times more than normal ice and has many applications in industries due to be hygienic and non-toxic.

Biogas installations are the best and the most economic way known in many countries round the world to solve the problems including the deficiency of energy, pathogenesis, cure cost and the environmental pollutions, as these systems prevent from the dispersion of animal excrement and thus the spread of diseases in rural regions.

Based on the performed studies, collection of animal excrement in the biogas system causes fly production to decrease by %90 and mouse production by %65 and by the energy obtained from it, the villagers no longer need to cut forest trees and in this way forests and pastures are protected against destruction.

The methane gas extracted from the sites of burying urban garbage and waste waters could be used in order to produce electric energy or the needed hot water for the adjacent regions. Using the combustible methane gas would prevent from its entrance into the earth's atmosphere and thus the global heating, as its concentration has increased in recent years and according to the conducted studies, the earth's temperature might increase by 0.2 to 0.3^oc with doubling methane concentration. The establishment and development of biogas units has been initiated in most of the countries round the world in small and large scale from past decades. Among these countries, China has the first grade not only in the Asia but also around the world, from the aspect of number, spreading and the technology of biogas units in villages and industries. So that thousands of large and average sized biogas equipment are used in food factories, large animal husbandries and fermentative industries, the production of driving force and large agricultural fields. In general, establishing biogas units follows two main purposes. Hygienic burial of excrement and waste materials and the production of energy. The establishment and development of such units in the country needs appropriate study and programming, the government helps include financial aids(subsidy payment and donating low- profit loans), the establishment of organizations to represent total helps(technical and consultative) and also training people and informing them about the advantages and positive points of these units.

B- BIOMETHANATION PLANTS AND DIGESTORS

A typical biological gasification unit or biomethanation plant may have many subunits for different steps. These subunits include hydrolysis units with an optional pretreatment stage, anaerobic digesters, gas clean-up and dehydration units, and liquid effluent treatment units. Advanced designs presently being used include two-phase, plug-flow, packed-bed, and fluidized bed digestors. Anaerobic installations for waste treatment are called *digestors*. The primary process in methanogenesis is the digestion of organic material to soluble and gaseous products. In many waste treatment systems, the main objective has not been the production of methane as an energy source, but the stabilization of sludge so that it can be safely disposed of in the environment[11].

In such systems, little attention has been paid to optimizing the methanogenesis process. Various treatment plants collect biogas generated in digestors, which is then used to fuel the plants. In these anaerobic digestors, contrary to aerobic processes, some significant advantages exist. Energy expenditure for aeration is not required, which saves considerably on operating costs. In such digestors, organic wastes and residues are converted more than 90 percent to methane and carbon dioxide. Bacterial biomass formation is very low under anaerobic conditions; consequently, the cost of sludge disposal is lower. In addition, odor problems are decreased since the digestion process is carried out in closed

digestors and the methane is collected. Therefore, the advantage of these digestors is that the produced gas can be easily removed from the top of the system and stored for its utilization as an energy source. However, solid wastes and residues are the suitable starting materials for anaerobic digestions. The more diluted liquid wastes are primarily treated in aerobic activated-sludge processes. Because of the low microbial biomass formed in such fermentation processes and low energy yield, the rate of the digestion process is slow. The average residence time in the digester may exceed 20 days. Immobilization of microorganisms in a fixed-bed reactor can be used to increase the concentration of cells. Such fixed-bed reactors are very useful in treating solutions with very high organic loads in shorter periods. Some research has been carried out using porous sintered glass as carrier material for fixed-bed reactors.

Using such a reactor with a capacity of 1000 litres, a considerable reduction in the biological oxygen demand (BOD) from 6.4 to 1.3 kg/m³ could be achieved in just 4.8 hours. In a different installation for the treatment of high-concentration wastes obtained from a fermentation plant, the digestion process was carried out in two stages. The first digester was used for acid production and the second reactor was used for biomethanogenesis. The size of both reactors was 380 m³, and sand was used as the carrier. In a two-stage system such as this, waste volumes of 150-200 m³ per hour could be treated within 1 to 1.5 hours, and the digestion of wastes could be achieved up to 30 kg chemical oxygen demand (COD) per m³ per day.

C- SUBSTRATES FOR BIOGAS PRODUCTION SUBSTRATES FOR ANAEROBIC DIGESTION

The most commonly used substrates for anaerobic digestion are agricultural residues, food and agro-industrial wastes, cattle dung, poultry and piggery wastes, sewage, and sludge. The types of wastes may include crop wastes and residues, vegetables and tubers, sugar, starch, and confectionery; grains, legumes, oilseeds, wastes from distilleries, wineries, and breweries; plantation products, milk and dairy wastes, meat, poultry, fish wastes, marine products, and eggs. Many other sources of biomass exist that have a load of organic matter suitable for digestion. Studies have been done to produce biogas from the biomass of the water hyacinth, which grows in excessive amount in canals and streams in tropical countries. In theory, 800 m³ of biogas can be produced under optimal conditions from the digestion of about two tons dry mass per day.

D- SUBSTRATES FOR METHANOGENESIS

Methanogenic bacteria constitute a unique group of organisms that are the final and key link in the breakdown of organic matter in the anaerobic food chain. These bacteria are able to utilize only a restricted group of substrates for the synthesis of methane, including acetate, methanol, and formate, hydrogen, and carbon dioxide. In waste disposal

systems, about 75 percent of the methane is synthesized from acetate, and most of the rest from hydrogen and carbon dioxide. Although the starting materials of the anaerobic decomposition process are complex polymeric materials, such as cellulose, starch, fats, and proteins, none of these can be utilized by methanogenic bacteria. Therefore, other anaerobic fermentative organisms are required for the initial breakdown of polysaccharide and polymer compounds for the production of intermediate substrates, which can then be utilized by methanogenic bacteria.

E- EFFECT OF SUBSTRATES

The rate of methanogenesis is affected by the nature of the substrate used in digesters as well as the temperature of digestion. With mixed sludge, up to 600 litres of biogas per kg dry substrate can be produced. This biogas consists of about 60 to 70 percent methane and 25 to 30 percent carbon dioxide with the rest being hydrogen and nitrogen. Tropical countries have a wide variety of agro-industrial residues from agriculture and food industries, which are the most useful substrates for anaerobic digestion. Developing countries present the most promising areas for the development of biogas production, particularly because energy is in short supply and waste disposal is generally difficult to be carried out by those processes that are in operation in developed countries. Therefore, the efficiency of the process in developing countries is not as important as the energy produced. Among the intermediary compounds produced in the digestion process, acetate is the main precursor, since two moles of methane are produced from acetate and one mole from carbon dioxide and hydrogen. Acetate is produced from the degradation of lipids and many fatty acids, including propionic, butyric, valeric, and long-chain fatty acids. These substrates undergo the following chemical reactions during methanogenesis:

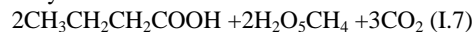
Acetic acid



Propionic acid



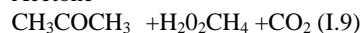
Butyric acid



Ethanol

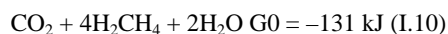


Acetone



Virtually any organic compound can be converted to methane and carbon dioxide in cooperative reactions involving methanogens and other anaerobic bacteria. At least ten substrates have been shown to be converted to methane by pure cultures of methanogens. These substrates do not

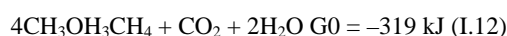
include common compounds such as glucose and organic or fatty acids (other than acetate). Three groups of compounds are included in the list of ten methanogenic substrates. The first group includes CO_2 -type compounds: carbon dioxide (with electrons derived from hydrogen, certain alcohols, or pyruvate), formate, and carbon monoxide. Carbon dioxide is reduced to methane using hydrogen as an electron donor:



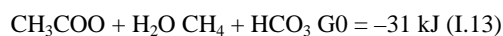
The second group of compounds includes methyl substrates such as methanol, methylamine, dimethylamine, trimethylamine, methylmercaptan, and dimethylsulfide. Using methanol as a model, the formation of methane can occur in either of two ways. First, methanol can be reduced using an external electron donor such as hydrogen:



In the absence of hydrogen, some methanol can be oxidized to carbon dioxide in order to generate some electrons needed to reduce other molecules of methanol to methane:



The third group includes acetotrophic substrates such as acetates. The final methanogenic process is the cleavage of acetate to carbon dioxide and methane. This process is known as the acetotrophic reaction:



Very few methanogens are acetotrophic, but experimental measurements of methane formation in methanogenic habitats, e.g., sewage sludge, have revealed that about two-thirds of the methane is actually formed from acetate and one-third from hydrogen and carbon dioxide. Although lacking in terms of known diversity, acetotrophic methanogens are obviously very ecologically significant organisms in nature.

II. CONCLUSION AND DISCUSSION

The performed investigations on the practical study of using biogas in IRAN show that, because of the following reasons, the biogas production industry in the country must be more noticed, in order that this low-cost natural resource could be utilized publicly and at least in the rural societies of IRAN.

Although IRAN is considered as one of the important poles in the world from the aspect of fossil reserves, cutting and burning forest trees as fuel is a social problem because of the difficulty of accessing oil and especially gas. This act, apart from the air pollution, leads to important problems such as flood, the destruction of places and the killing people. On the other hand, the rural societies of IRAN which include generally the poor and the low-earning population comprise a

considerable part of population whose main jobs are agriculture and animal husbandry. Accessing the cheap and easily achievable energy resources in this group is of much importance.

In recent years, the increasing trend of energy consumption has led to the energy crisis phenomenon in the world, which is more intense in the developing countries including IRAN. Facing this crisis is through the use of the new technologies for producing energy and the replacement of other sources. Fossil fuels especially oil and gas, are considered the most important source of national income which has an annual growth of %5-10. This illustrates that apart from the damaging environmental effects and the air pollution, no reserve will remain for export in the future. Therefore, the new technologies for producing energy including biogas must be considered specifically in the development programs of the country.

The statistic and data show that a great amount of garbage, human and animal excrement and also a significant amount of organic wastes are produced annually in the agriculture sector. These organic compounds, which are easily decomposed and converted into simpler first materials, cause problems in the fields of disposal or different hygienic issues. Economically, by running and utilizing biogas producing equipment, a great saving on energy consumption and especially on fossil fuels is occurred and meanwhile the mentioned environmental and hygienic problems and issues are solved. Although the technology of biogas production unfortunately much interested in Western Europe and the south east of Asia and especially in China and India.

Now a days, the combustion of fossil fuels is considered the most important source of producing contaminants and the dispersion amount of these materials has exceeded the allowed limit in most of the big cities in IRAN; this phenomenon affects the health of human being, plants and even animals, directly and indirectly. Biogas with high thermal energy is a reliable alternative source, as it is a kind of natural gas, which is free sulfur. Biogas, as the best and cleanest fuel derived from the natural gas, does not lead to air pollution and thus has an effective role in the protection of the environment and the public health.

Biomethanogenesis or biogas technology has important implications in the area of energy, agriculture, farming, and pollution control for a cleaner environment; hence there is a need for vigorous efforts to promote its usefulness. This technology offers several advantages, such as providing clean fuel for rural areas, promoting a safe and clean environment by the recycling of waste materials, and producing nutrient-rich organic manure.

Biogas technology is very simple and cheap and it could be easily installed and runned in different areas and especially in the villages of the country. The existence of wastes in the agriculture sector and the high volume of garbage and animal and human excrement produced in each village and also the simplicity of biogas operation in its necessitate the optimized application of organic residues in order to produce energy. It

should be noted that this kind of energy could be easily reserved and used to bake bread or as a fuel in the bathroom and as the driving force for the agricultural water pumps.

REFERENCES

- [1] Jose' C. Escobar a, Electo S. Lora a*, Osvaldo J. Venturini a, Edgar E. Ya'n'ez b, Edgar F. Castillo c, Oscar, Almazan , "Biofuels: Environment, technology and food security, Renewable and Sustainable Energy Reviews 13," 2009, pp. 1275-1287.
- [2] International Energy Agency IEA. Key world energy statistics; 2006. Available in: <http://www.iea.org/Textbase/nppdf/free/2006/Key2006.pdf>. Accessed: 07/06/2007.
- [3] Teske S, Scha"fer O. Energy revolution: a sustainable world energy outlook. Renewable Energy World; 2007. Available in: <http://www.renewable-energyworld.com>. Accessed: 15/03/2007.
- [4] Kong L, Li G, Zhang B, He W, Wang H., "Hydrogen production from biomass wastes by hydrothermal gasification," . Energy Sources Part A 2008;30:1166-78.
- [5] Balat M., "Possible methods for hydrogen production," Energy Sources Part A, 2009;31:39-50.
- [6] Optner, S. L., 1997, "System Analysis". Penguin Books Ltd, Harmondsworth, Middlesex, England. Sathianathan, M. A. (1975) "Biogas Achievements and Challenges". Association of Voluntary Agencies of Rural Development, New Delhi, India.
- [7] Intergovernmental Panel on Climate Change—IPCC. "The physical science basis". Working Group I Report; 2007. Available in: <http://www.ipcc.ch>. Accessed: 20/09/07.
- [8] Conn I. Energy trends and technologies for the coming decades. Address to the Harvard University Center for the Environment; 2007.
- [9] Intergovernmental Panel on Climate Change – IPCC. "Cambio clima' ticoybiodiversidad". Working Group II Report; 2001. Available in: <http://www.ipcc.uch>. Accessed: 10/05/07.
- [10] Intergovernmental Panel on Climate Change—IPCC. Mitigation from a crosssectorial perspective. Working Group III Report, Mitigation of Climate Change—Chapter 11; 2007. Available in: <http://www.ipcc.ch>. Accessed: 20/09/07.
- [11] Ashok Pandey, "Concise Encyclopedia of Bioresource," part I: Environmental Biotechnology, Biomethanation Plants and Digestors, ,Food Products Press®, The Haworth Reference Press, imprints of The Haworth Press, Inc., 2004, pp: 54-58.



Dr. Kambiz Tahvildari was born in TEHRAN, IRAN, on 09/22/1972.

He completed his Bachelors in Applied chemistry from the Islamic Azad University, Center Tehran Branch in 1996, Masters in Applied Chemistry from the IAU, North Tehran Branch in 1998 and Ph.D in Applied chemistry from the IAU, North Tehran Branch in 2005. He is inspector, responsible of r&d and assistant professor department of Applied Chemistry from the IAU, North Tehran Branch. He

also taught various courses at the IAU, North Tehran Branch. He has experiences about 10 years in various areas including organic and inorganic chemistry, Alternative & Renewable Energy; teaching; business & technical consultant; project manager and launching 2 research labs at IAU, North Tehran Branch.

He has registered 7 patent and written 7 papers in technical journals and presented papers in large number of national and International conferences, workshops etc. He has been actively involved in preparing a large number of project reports/ studies implementation of Ethanol & biodiesel projects. Dr. Kambiz Tahvildari is a member of IRANIAN Academy of Chemical Engineering since 2005 until Now.