ADVANTAGES AND LIMITATIONS OF BIOGAS TECHNOLOGIES

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Abstract

Biogas systems turn the cost of waste management into a revenue opportunity for farms, dairies, and industries. Converting waste into electricity, heat, or vehicle fuel provides a renewable source of energy that can reduce dependence on foreign oil imports, reduce greenhouse gas emissions, improve environmental quality, and increase local jobs. Biogas systems also provide an opportunity to recycle nutrients in the food supply, reducing the need for both petrochemical and mined fertilizers.

The present paper gives a complete idea on the prospective technology for the production of clean energy in the form of biogas. Biogas is green and a sustainable energy consisting of methane to a great extent along with other gases. Global warming and greenhouse effect are caused due to the harmful gases which are released into the atmosphere. Emission from automobiles and industries are one of the causes of global warming. Along with global warming the excessive use of fossil fuels shifts the balance of supply of fuels. So in order to save fossil fuels for our future generations alternative fuels play an important role in replacing the fossil fuels. The present paper gives an idea of the history of biogas and their advantages and disadvantages.

Keywords: History of biogas, advantages, disadvantages, global warming, fossil fuels

1. Introduction

Biogas is a combustible mixture of gases [1] (see Fig. 1). It consists mainly of methane (CH_4) and carbon dioxide (CO_2) and is formed from the anaerobic bacterial decomposition of organic compounds, i.e. without oxygen. The gases formed are the waste products of the respiration of these decomposer microorganisms and the composition of the gases depends on the substance that is being decomposed. If the material consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicellulose, the methane production is low. However, if the fat content is high, the methane production is likewise high. Methane – and whatever additional hydrogen there may be – makes up the combustible part of biogas. Methane is a colorless and odorless gas with a boiling point of -162°C and it burns with a blue flame. Methane is also the main constituent (77- 90%) of natural gas. Chemically, methane belongs to the alkanes and is the simplest possible form of these. At normal temperature and pressure, methane has a density of approximately 0.75 kg/m^3. Due to carbon dioxide being somewhat heavier, biogas has a slightly higher density of 1.15 kg/m^3. Pure methane has an upper calorific value of 39.8 MJ/m^3, which corresponds to 11.06 kWh/ m^3. If biogas is mixed with 10-20% air, you get explosive air.

The production and utilization of biogas from anaerobic digestion provides environmental and socioeconomic benefits for the society as a whole as well as for the involved farmers. Utilization of the internal value chain of biogas production enhances local economic capabilities, safeguards jobs in rural areas and increases regional purchasing power. It improves living standards and contributes to economic and social development.

Worldwide interest in renewable energy sources is gathering momentum. Biogas production is growing steadily, as more people are setting up biogas plants to produce biogas. To get a better picture of what biogas is good for, the advantages and disadvantages of biogas is mentioned in this research paper.

2. The History of Biogas Production

People have known of the existence of naturally produced biogas since the 17th century and experiments with the construction of actual biogas systems and plants started as early as the mid-19th century. One of the oldest biogas systems is the septic tank, which has been used for the treatment of wastewater since the end of the 19th century and is still used for isolated properties where there is no sewerage system. In this type of plant the biogas is, however, not collected and used.

Gas	%
Methane (CH_4)	55 – 70
Carbon dioxide (CO_2)	30 – 45
Hydrogen sulphide (H_2S)	1 – 2
Hydrogen (H_2)	1 – 2
Ammonia (NH_3)	1 – 2
Carbon monoxide (CO)	trace
Nitrogen (N_2)	trace
Oxygen (O_2)	trace

Fig. 1. Composition of biogas

In the 1890s, the Englishman Donald Cameron constructed a special septic tank, from which the gas was collected and used for street lighting. In Denmark the construction of biogas plants for wastewater treatment started in the 1920s. The gas was initially used to heat the plant's digester tank and the main purpose was therefore not to extract energy, but to decompose organic matter in the wastewater and thus reduce and stabilize the sludge, which is a product of the treatment process.
In the following period and until shortly after the Second World War, there was a substantial growth in the biogas industry, particularly in Germany, Britain and France, and the technology also gradually found its way into agriculture with energy production as the main purpose.
At the end of the 1950s, development nearly stopped, however, due to the cheapness of the fossil fuels oil and gas. The interest in biogas was not reawakened until the mid-1970s following
the oil crisis in 1973. The Danish state initiated a research and development program with the aim of testing and constructing different types of biogas plants using animal manure as the main source of biomass.
In 2009 there are about 60 biogas facilities installed at sewage treatment plants. In addition, around 20 communal biogas plants of various sizes have been constructed to treat manure, slurry in particular, from a number of livestock farms. These biogas plants also take in large amounts of organic waste from the food industry and slaughterhouses, whereby the energy from the waste is extracted and the nutrients recycled to the agricultural sector. On top of this, there are approximately 60 on-farm facilities and a number of biogas plants associated with landfill sites and with different industries that produce waste water with a high organic content (see Fig. 2). From the mid-1990s, the expansion of the biogas sector once again stagnated in Denmark due to lack of economic incentives. But with the political agreement in Folketinget in 2008 on an energy policy promoting green energy and on a better price for electricity produced from biogas, the sector is slowly starting to wake up again.

	Number	Biogas production in Denmark in 2006 1,000 m^3
Municipal sewage treatment plants	61	~ 40,000
Communal biogas plants	19	~ 73,000
Farm biogas plants	57	~ 33,000
Landfill gas plants	25	~ 18,000
Industrial plants	5	~ 7,000
Total	167	~ 171,000

Total biogas production in Denmark is 4 PJ, which is about 5‰ of the total energy consumption.

Fig. 2. Biogas production in Denmark in 2006

3. Advantages of Biogas Technology

A. Renewable Energy Source

The current global energy supply is highly dependent on fossil sources (crude oil, lignite, hard coal, natural gas). These are fossilized remains of dead plants and animals, which have been exposed to heat and pressure in the Earth's crust over hundreds of millions of years. For this reason, fossil fuels are non-renewable resources which reserves are being depleted much faster than new ones are being formed The World's economies are dependent today of crude oil. There is some disagreement among scientists on how long this fossil resource will last but according to researchers, the peak oil production which is defined as "the point in time at which the maximum rate of global production of crude oil is reached, after which the rate of production enters its terminal decline" has already occurred or it is expected to occur within the next period of time [2] (Fig. 3).

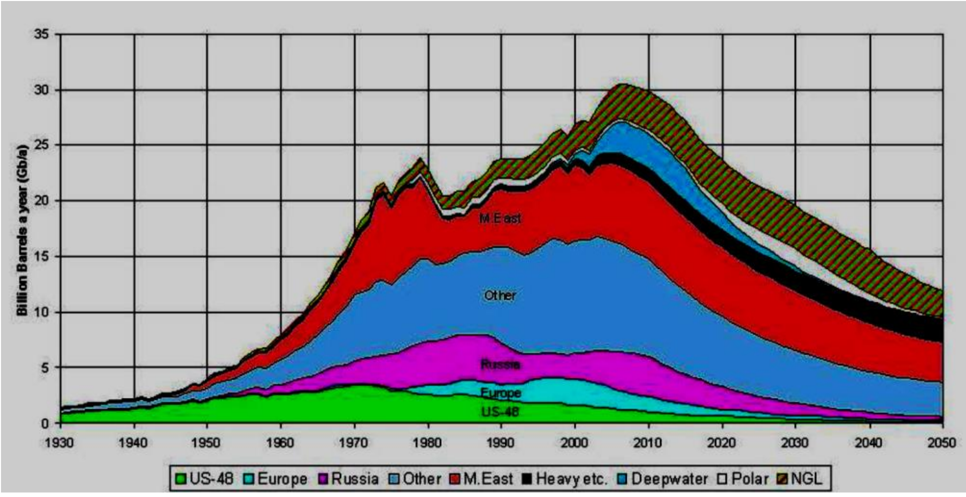

Fig. 3 Scenario of World oil production and "peak oil" (ASPO 2008)

Unlike fossil fuels, biogas from anaerobic digestion is permanently renewable, as it is produced on biomass, which is actually a living storage of solar energy through photosynthesis. Biogas from AD will not only improve the energy balance of a country but also make an important contribution to the preservation of the natural resources and to environmental protection.

B. Reduced Greenhouse Gas Emissions and Mitigation of Global Warming

Utilization of fossil fuels such as lignite, hard coal, crude oil and natural gas converts carbon, stored for millions of years in the Earth's crust, and releases it as carbon dioxide (CO_2) into the atmosphere. An increase of the current CO_2 concentration in the atmosphere causes global warming as carbon dioxide is a greenhouse gas (GHG). The combustion of biogas also releases CO_2. However, the main difference, when compared to fossil fuels, is that the carbon in biogas was recently up taken from the atmosphere, by photosynthetic activity of the plants. The carbon cycle of biogas is thus closed within a very short time (between one and several years). Biogas production by AD reduces also emissions of methane (CH_4) and nitrous oxide (N_2O) from storage and utilization of untreated animal manure as fertilizer. The GHG potential of methane is higher than of carbon dioxide by 23 fold and of nitrous oxide by 296 fold. When biogas displaces fossil fuels from energy production and transport, a reduction of emissions of CO_2, CH_4 and N_2O will occur, contributing to mitigate global warming.

C. Reduced Dependency on Imported Fossil Fuels

Fossil fuels are limited resources, concentrated in few geographical areas of our planet. This creates, for the countries outside this area, a permanent and insecure status of dependency on import of energy. Most European countries are strongly dependent on fossil energy imports from regions rich in fossil fuel sources such as Russia and the Middle East. Developing and implementing renewable energy systems such as biogas from AD, based on national and regional biomass resources, will increase security of national energy supply and diminish dependency on imported fuels.

D. Contribution to EU Energy and Environmental Targets

Fighting the global warming is one of the main priorities of the European energy and environmental policies. The European targets of renewable energy production, reduction of GHG emission, and sustainable waste management are based on the commitment of the EU member states to implement appropriate measures to reach them. The production and utilization of biogas from anaerobic digestion has the potential to comply with all three targets at the same time.

E. Waste Reduction

One of the main advantages of biogas production is the ability to transform waste material into a valuable resource, by using it as substrate for anaerobic digestion. Many European countries are facing enormous problems associated with overproduction of organic wastes from industry, agriculture and households. Biogas production is an excellent way to comply with increasingly restrictive national and European regulations in this area and to utilize organic wastes for energy production, followed by recycling of the digested substrate as fertilizer. Anaerobic digestion can also contribute to reducing the volume of waste and of costs for waste disposal.

F. Job Creation

Production of biogas from anaerobic digestion requires work power for production, collection and transport of anaerobic digestion feedstock, manufacture of technical equipment, construction, operation and maintenance of biogas plants. This means that the development of a national biogas sector contributes to the establishment of new enterprises, some with significant economic potential, increases the income in rural areas and creates new jobs.

G. Flexible and Efficient End Use of Biogas

Biogas is a flexible energy carrier, suitable for many different applications. One of the simplest applications of biogas is the direct use for cooking and lighting, but in many countries biogas is used nowadays for combined heat and power generation (CHP) or it is upgraded and fed into natural gas grids, used as vehicle fuel or in fuel cells.

H. Low Water Inputs

Even when compared to other biofuels, biogas has some advantages. One of them is that the anaerobic digestion process needs the lowest amount of process water. This is an important aspect related to the expected future water shortages in many regions of the world.

I. Additional Income for the Farmers Involved

Production of feedstock in combination with operation of biogas plants makes biogas technologies economically attractive for farmers and provides them with additional income. The farmers get also a new and important social function as energy providers and waste treatment operators.

J. Digestive is an Excellent Fertilizer

A biogas plant is not only a supplier of energy. The digested substrate, usually named digestive, is a valuable soil fertilizer, rich in nitrogen, phosphorus, potassium and micronutrients, which can be applied on soils with the usual equipment for application of liquid manure. Compared to raw animal manure, digestive has improved fertilizer efficiency due to higher homogeneity and nutrient availability, better C/N ratio and significantly reduced odor.

K. Closed Nutrient Cycle

From the production of feedstock to the application of digestive as fertilizer, the biogas from anaerobic digestion provides a closed nutrient and carbon cycle (Fig. 4) [3]. The methane (CH_4) is used for energy production and the carbon dioxide (CO_2) is released to the atmosphere and retaken by vegetation during photosynthesis. Some carbon compounds remain in the digestive, improving the carbon content of soils, when digestive is applied as fertilizer. Biogas production can be perfectly integrated into conventional and organic farming, where digestive replaces chemical fertilizers, produced with consumption of large amounts of fossil energy.

L. Flexibility to Use Different Feedstock

Various types of feedstock can be used for the production of biogas: animal manure and slurries, crop residues, organic wastes from dairy production, food industries and agro industries, wastewater sludge, organic fraction of municipal solid wastes, organic wastes from households and from catering business as well as energy crops. Biogas can also be collected, with special installations, from landfill sites. One main advantage of biogas production is the ability to use "wet biomass" types as feedstock, all characterized by moisture content higher than 60–70% (e.g. sewage sludge, animal slurries, flotation sludge from food processing etc.). In recent years, a number of energy crops (grains, maize, rapeseed), have been largely used as feedstock for biogas production in countries like Austria or Germany. Besides energy crops, all kinds of agricultural residues, damaged crops, unsuitable for food or resulting from unfavorable growing and weather conditions, can be used to produce biogas and fertilizer. A number of animal by-products, not suitable for human consumption, can also be processed in biogas plants.

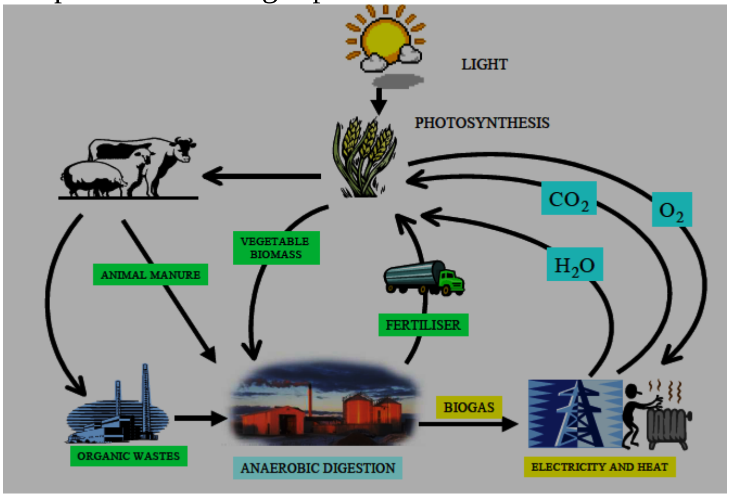

Fig. 4 The sustainable cycle of biogas from AD

M. Reduced Odor and Flies

Storage and application of liquid manure, animal dung and many organic wastes are sources of persistent, unpleasant odor and attract flies. AD reduces these odors by up to 80% (Fig. 5). Digestive is almost odorless and the remaining ammonia odors disappear shortly after application as fertilizer[4].

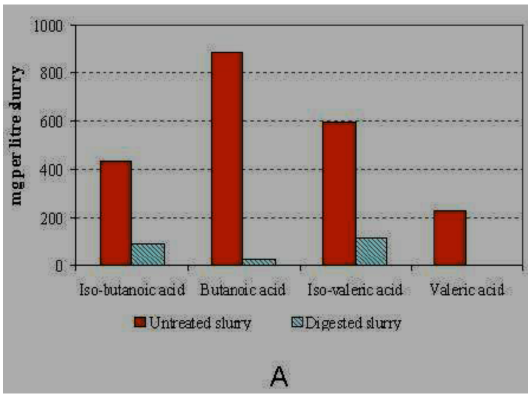

Fig. 5A Concentration of odours in untreated slurry and in digested slurry

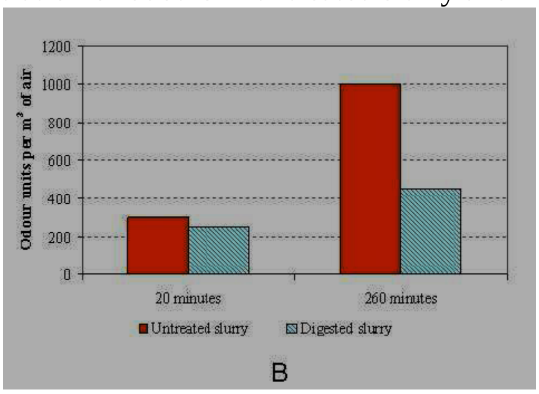

Fig. 5B Odour concentration in air

N. Veterinary Safety

Application of digestive as fertilizer, compared to application of untreated manure and slurries, improves veterinary safety. In order to be suitable for use as fertilizer, digestive is submitted to a controlled sanitation process. Depending of the type of feedstock involved, sanitation can be provided by the anaerobic digestion process itself, through a minimum guaranteed retention time of the substrate inside the digester, at thermophilic temperature, or it can be done in a separate process step, by pasteurization or by pressure sterilization. In all cases, the aim of sanitation is to inactivate pathogens, weed seeds and other biological hazards and to prevent disease transmission through digestive application [5] – [13].

4. Limitations of Biogas Technology

A. The Impact of Methane on the Climate

Human activities such as cattle farming, rice farming and the accumulation of waste on large waste disposal sites, etc., are thought to have caused a doubling of the atmospheric concentration of methane to the present level of 1.7 ppm. This does not, as such, have any effect on human health. However, as methane is part of the chemical processes in the atmosphere and is also a powerful greenhouse gas (about 22 times as powerful as carbon dioxide, CO_2), the gas is a contributor to the greenhouse effect. Methane has thus contributed about 20% to the total increase in the greenhouse effect caused by human activities. If the greenhouse effect results in an increasing temperature rise on our planet, there is a risk that the large areas of tundra currently under permafrost will slowly thaw, which will result in the release of huge quantities of methane when organic materials are gradually decomposed. This will obviously further exacerbate the greenhouse effect. Methane in large quantities also destroys ozone. Rising methane emissions can therefore have unfortunate consequences for the ozone layer that helps protect the Earth against the harmful ultraviolet radiation from the sun.

B. Few Technological Advancements

An unfortunate disadvantage of biogas today is that the systems used in the production of biogas are not efficient. There are no new technologies yet to simplify the process and make it abundant and low cost. This means large scale production to supply for a large population is still not possible. Although the biogas plants available today are able to meet some energy needs, many governments are not willing to invest in the sector.

C. Contains Impurities

After refinement and compression, biogas still contains impurities. If the generated bio-fuel was utilized to power automobiles, it can corrode the metal parts of the engine. This corrosion would lead to increased maintenance costs. The gaseous mix is much more suitable for kitchen stoves, water boilers, and lamps.

D. Effect of Temperature on Biogas Production

Like other renewable energy sources (e.g. solar, wind) biogas generation is also affected by the weather. The optimal temperature bacteria need to digest waste is around 37°C. In cold climates, digesters require heat energy to maintain a constant biogas supply.

E. Less Suitable For Dense Metropolitan Areas

Another biogas disadvantage is that industrial biogas plants only makes sense where raw materials are in plentiful supply (food waste, manure). For this reason, biogas generation is much more suitable for rural and suburban areas.

5. Conclusions

Renewable energy is The future sustainable green energy. Utilization of biogas reduces global warming, dependency on Imported Fossil Fuels, waste, and odor, it also increases the opportunity of job creation for farmers and the community at large thereby reducing unemployment. It also enlarges the flexibility to use different feedstock and contributes to EU energy and environmental targets. Very little technological advancements have been made or introduced for streamlining and making the process cost effective and hence the systems that are currently used are not efficient enough. Hence, even the large scale industrial production of biogas is not shown or isn't visible on the energy map [14]. Most investors are not willing to put in their capital investments in the production of biogas, although investments could be a possible solution to the problems being faced. An unfortunate disadvantages of biogas today are the detrimental impact of methane on the climate, the systems used in the production of biogas are not efficient and it is less suitable for dense metropolitan areas.

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