

CHAPTER ONE

INTRODUCTION

1.1 Background

Conventional energy is energy which is taken from the sources that are available in limitation quantity and will vanish fifty-sixty years from now. Conventional source are not environmental friendly and can have serious effect on our health. They are called Non-renewable energy because they cannot be re-generated within a short span of time. Conventional sources exist in the form of fossil fuel, natural gas, oil and coal. Conventional sources will expire some day and we have to use our endangered resources to create more Conventional sources of energy, The speed at which such resources are being utilized can have serious environmental changes, on-renewable sources release toxic gases in the air when burnt which are the major cause for global warming and these sources are going to expire soon, prices of these sources are soaring day by day.

Renewable energy is the energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as and when required. They are available in plenty and by far most the cleanest sources of energy available on this planet. There are many pros of using renewable sources of energy such as they are available in the abundant quantity and free to use, renewable sources have low carbon emissions, therefore they are considered as green and environment friendly, renewable helps in stimulating the economy and creating job opportunities, You don't have to rely on any third country for the supply of renewable sources as in case of non-renewable sources, renewable sources can cost less than consuming the local electrical supply. In the long run, the prices of electricity are expected to soar since they are based on the prices of crude oil, so renewable sources can cut your electricity bills, various tax incentives in the form

of tax waivers, credit deductions are available for individuals and businesses who want to go green. [1]

Wind power is one of the renewable energy sources which has been widely developed in recent years. Wind energy has many advantages such as no pollution, relatively low capital cost involved and the short gestation period. The first wind turbine for electricity generation was developed at the end of the 19th century. From 1940 to 1950, two important technologies, i.e., three blades structure of wind turbine and the AC generator which replaced DC generator were developed. At the end of 1990s, wind power had an important role in the sustainable energy. Wind energy is the fastest growing energy source.

The energy of solar irradiance to produce electricity using photovoltaics' (PV) and concentrating Solar power (CSP), to produce thermal energy (heating or cooling, either through passive or active means), to meet direct lighting needs and, potentially, to produce fuels that might be used for transport and other purposes. Photovoltaic is the conversion of light directly into electricity through semiconductor materials. [1]

Hydropower Harnesses the energy of water moving from higher to lower elevations, primarily to generate electricity. Hydropower projects encompass dam projects with reservoirs, run-of-river and in-stream projects and cover a continuum in project scale. This variety gives hydropower the ability to meet large centralized urban needs as well as decentralized rural needs. Hydropower projects exploit a resource that varies temporally. However, the controllable output provided by hydropower facilities that have reservoirs can be used to meet peak electricity demands and help to balance electricity systems that have large amounts of variable regeneration. The operation of hydropower reservoirs often reflects their multiple uses, for example, drinking water, irrigation, flood and drought control, and navigation, as well as energy supply. [1]

Bio energy one excellent source of energy is Biogas. This is produced when bacteria decompose organic material such as garbage and sewage, especially in the absence of oxygen. Biogases mixture of about 60 percent methane and 40 percent Carbon dioxide. Methane is the main component of natural gas. It is relatively clean burning, colorless, and odorless. This gas can be captured and burned for cooking and heating. This is already being done on a large scale in some countries of the world. Farms that produce a lot of manure, such as hog and dairy farms, can use biogas generators to produce methane. [1]

1.2 State of problem

One of the main environmental problems of today's society is the continuously increasing production of organic wastes. In many countries, sustainable waste management as well as waste prevention and reduction have become major political priorities, representing an important share of the common efforts to reduce pollution and greenhouse gas emissions and to mitigate global climate changes. Uncontrolled waste dumping is no longer acceptable today and even controlled landfill disposal and incineration of organic wastes are not considered optimal practices, as environmental standards here of are increasingly stricter and energy recovery and recycling of nutrients and organic matter is aimed. Production of biogas through anaerobic digestion (AD) of animal manure and slurries as well as of a wide range of digestible organic wastes, converts these substrates into renewable energy and offers a natural fertilizer for agriculture. At the same time, it removes the organic fraction from the overall waste streams, increasing this way the efficiency of energy conversion by incineration of the remaining wastes and the biochemical stability of landfill sites. AD is a microbiological process of decomposition of organic matter, in the absence of oxygen, common to many natural environments and largely applied today to produce biogas in airproof reactor tanks, commonly named digesters. A wide

range of micro-organisms are involved in the anaerobic process which has two main end products biogas and digest ate. Biogas is a combustible gas consisting of methane, carbon dioxide and small amounts of other gases and trace elements. Digest ate is the decomposed substrate, rich in macro- and micro nutrients and therefore suitable to be used as plant fertilizer.

One of important problem today the electricity don't arrived to rural area and we can used biogas to produce electricity in this area.

1.3 Objectives

The main of the research are summarized as follow:-

- 1- Production of biogas from animal waste.
- 2- Generation of electricity from hybrid system consist of biogas unit and diesel unit.
- 3- Study the system performance

1.4 Thesis lay-out

The thesis is organized as follow:-

Chapter one: - summarized research problem and objectives, also it give brief introduction about renewable and conventional energy.

Chapter two: - this chapter illustrates Generation of biogas and effected factors.

Chapter three: - biogas hybrid system.

Chapter four: -this chapter consist the unit design of biogas and the modulation.

Chapter five : - this chapter shows the final results in conclusion and recommendations.

CHAPTER TWO

BIOGAS GENERATION

2.1 Introduction

The production and utilization of biogas from AD provides environmental and socio-economic 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. The biochemical process of AD As previously stated, AD is a microbiological process of decomposition of organic matter in absence of oxygen. The main products of this process are biogas and digest ate. Biogas is a combustible gas, consisting primarily of methane and carbon dioxide. Digest ate is the decomposed substrate, resulted from the production of biogas. During AD, very little heat is generated in contrast to aerobic decomposition (in presence of oxygen), like it is the case of composting. The energy, which is chemically bounded in the substrate, remains mainly in the produced biogas, in form of methane. [1]

2.2 Types of Biomass

The six types of biomass are agricultural biomass, forest biomass, energy plantation, marine biomass, biomass from animal waste and municipal waste.

2.2.1 Agricultural biomass:-

Agricultural biomass which could be used for energy production is defined as biomass residues from field agricultural crops (stalks, branches, leaves, straw, waste from pruning, etc.) and biomass from the byproducts of the processing of agricultural products (residue from cotton ginning, olive pits, fruit pits, etc.).

2.2.2 Biomass from animal waste:-

The potential biomass from animal waste includes primarily waste from intensive livestock operations, from poultry farms, pig farms, cattle farms and slaughter-houses. The animal waste is a rich source of fuel. The dung cakes prepared with animal wastes can be used for meeting cooking energy requirement in rural and semi-urban areas.

2.2.3 Forest biomass:-

Forest biomass, which is used or can be used for energy purposes consists of firewood, forestry residues (from thinning and logging), material cleared from forests to protect them from forest fires, as well as byproducts from wood industries.

2.2.4 Municipal waste:-

The municipal waste consists of solid wastes as human excreta, garbage, city wastes and commercial wastes. It also includes liquid form domestic sewage and effluent from community institutional activities. There are a number of ways these wastes can be recycled and resources recovered in terms of fuel gas, manure and liquid fuel, etc. [1]

2.3 GENERATION OF BIO-GAS

The process of biogas formation is a result of linked process steps, in which the initial material is continuously broken down into smaller units. Specific groups of micro-organisms are involved in each individual step. These organisms successively decompose the products of the previous steps. The simplified diagram of the AD process, shown in Figure highlights the four main process steps: hydrolysis, acid genesis, cytogenesis, and methanogens.

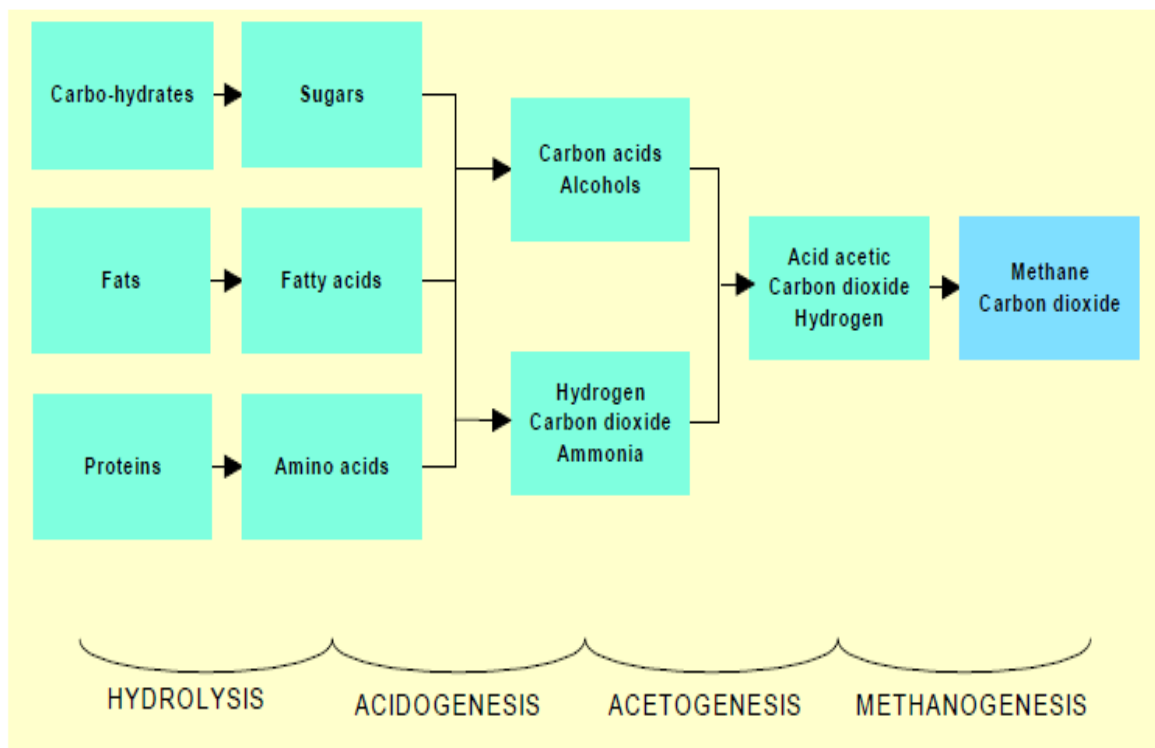


Figure 2.1 the simplified diagram of the AD process

When organic matter such as food, plant debris, animal manure, sewage sludge, biodegradable portions municipal solid waste, etc. Undergoes decomposition in absence of free oxygen, it normally generates a gas which consists of up to 65% methane, the rest being mostly carbon dioxide with traces of other gases. If ignited, this gas burns cleanly (i.e. gives off no soot or foul smell) similar to LPG (liquefied petroleum gas) or CNG (compressed natural gas). This gas is commonly called 'biogas' which is an inexact and imprecise term because the gas which is produced by aerobic decomposition (carbon dioxide) is also 'biogas' in the sense that it is also a result of bio degradation just as the other biogas is. But the word 'biogas' is used exclusively to denote the combustible $\text{CH}_4\text{-CO}_2$ mixture (beside traces of other gases) that is generated by the anaerobic decomposition of organic matter. Biogas has good calorific value, though lesser than LPG and CNG. [1]

2.4 The biochemical process of Anaerobic Digestion

2.4.1 Organic load

The construction and operation of a biogas plant is a combination of economical and technical considerations. Obtaining the maximum biogas yield, by complete digestion of the substrate, would require a long retention time of the substrate inside the digester and a correspondingly large digester size. In practice, the choice of system design (digester size and type) or of applicable retention time is always based on a compromise between getting the highest possible biogas yield and having justifiable plant economy. In this respect, the organic load is an important operational parameter, which indicates how much organic dry matter can be fed into the digester, per volume and time unit, according to the equation

Below:

$$\mathbf{BR = M * C / VR} \quad (2-1)$$

BR \equiv organic load [kg/d*m³]

M \equiv mass of substrate fed per time unit [kg/d]

C \equiv concentration of organic matter [%]

VR \equiv digester volume [m³]

2.4.2 Hydraulic retention time (HRT)

An important parameter for dimensioning the biogas digester is the hydraulic retention time (HRT). The HRT is the average time interval when the substrate is kept inside the digester tank. HRT is correlated to the digester volume and the volume of substrate fed per time unit, according to the following equation

$$\mathbf{HRT = VR / V} \quad (2-2)$$

HRT \equiv hydraulic retention time [days]

VR \equiv digester volume [m³]

V \equiv volume of substrate fed per time unit [m³/d]

According to the above equation, increasing the organic load reduces the HRT. The retention time must be sufficiently long to ensure that the amount of

microorganisms removed with the effluent (digest ate) is not higher than the amount of reproduced microorganisms. The duplication rate of anaerobic bacteria is usually 10 days or more. A short HRT provides a good substrate flow rate, but a lower gas yield. It's therefore important to adapt the HRT to the specific decomposition rate of the used substrates.

2.4.3 Hydrolysis

Hydrolysis is theoretically the first step of AD, during which the complex organic matter (Polymers) is decomposed into smaller units (mono- and oligomers). During hydrolysis, Polymers like carbohydrates, lipids, nucleic acids and proteins are converted into glucose, Glycerol, pureness and pyridines. Hydrolytic microorganisms excrete hydrolytic enzymes, Converting biopolymers into simpler and soluble compounds as it is shown below:

Lipids \longrightarrow lipase \longrightarrow fatty acids, glycerol

Polysaccharide \rightarrow cellulose, cellobiase, xylanase, amylase \longrightarrow monosaccharide

Proteins \rightarrow protease \longrightarrow amino acids

A variety of microorganisms is involved in hydrolysis, which is carried out by exoenzymes, produced by those microorganisms which decompose the undisclosed particulate material. The products resulted from hydrolysis are further decomposed by the microorganisms Involved and used for their own metabolic processes

2.4.4 Acid genesis

During acid genesis, the products of hydrolysis are converted by acidogenic (fermentative) bacteria into methanogenic substrates. Simple sugars, amino acids and fatty acids are degraded into acetate, carbon dioxide and hydrogen (70%) as well as into volatile fatty acids (VFA) and alcohols (30%).

2.4.5 Cytogenesis

Products from acid genesis, which cannot be directly converted to methane by methanogenic bacteria, are converted into methanogenic substrates during cytotogenesis. VFA Gas production rate or biogas yield Accumulated biogas yield (m^3/kg) Specific gas are oxidized into methanogenic substrates like acetate, hydrogen and carbon dioxide. VFA, with carbon chains longer than two units and alcohols, with carbon chains longer than one unit, are oxidized into acetate and hydrogen. The production of hydrogen increases the hydrogen partial pressure. This can be regarded as a „waste product “of cytotogenesis and inhibits the metabolism of the acetogenic bacteria. During methanogens, hydrogen is converted into methane. Cytogenesis and methanogens usually run parallel, as symbiosis of two groups of organisms.

2.4.6 Methanogens

The production of methane and carbon dioxide from intermediate products is carried out by methanogenic bacteria. 70% of the formed methane originates from acetate, while the remaining 30% is produced from conversion of hydrogen (H) and carbon dioxide (CO_2), according to the following equations:-

Acetic acid \longrightarrow methane + carbon dioxide

Hydrogen + carbon dioxide \longrightarrow methane + water

Methanogens is a critical step in the entire anaerobic digestion process, as it is the slowest biochemical reaction of the process. Methanogenesis is severely influenced by operation conditions. Composition of feedstock, feeding rate, temperature, and pH are examples of factors influencing the methanogens process. Digester overloading, temperature changes or large entry of oxygen can result in termination of methane production. [1], [2]

2.5 Anaerobic Digestion parameters

The efficiency of AD is influenced by some critical parameters, thus it is crucial that appropriate conditions for anaerobic microorganisms are provided. The growth and activity of anaerobic microorganisms is significantly influenced by conditions such as exclusion of Oxygen, constant temperature, pH-value, nutrient supply, stirring intensity as well as presence and amount of inhibitors (e.g. ammonia). The methane bacteria are fastidious anaerobes, so that the presence of oxygen into the digestion process must be strictly avoided.

2.5.1 Temperature

The AD process can take place at different temperatures, divided into three temperature Ranges: psychrophilic (below 25°C) mesospheric (25°C- 45°C) and hemophilic (45°C-70°C). There is a direct relation between the process temperature and the HRT.

Table 2.1 Thermal stage and typical retention times

Thermal stage	Process temperatures	Minimum retention time
Psychrophilic	< 20° C	70 to 80 days
Mesophilic	30° to 42° C	30 to 40 days
Thermophilic	43° to 55° C	15 to 20 days

The temperature stability is decisive for AD. In practice, the operation temperature is chosen with consideration to the feedstock used and the necessary process temperature is usually provided by floor or wall heating systems, inside the digester. Figure 2.2 shows the rates of Relative biogas yields depending on temperature and retention time.

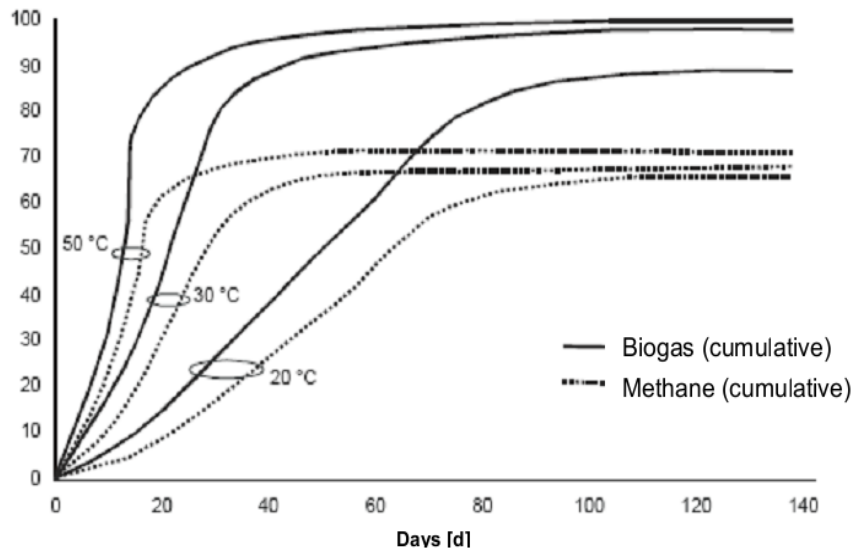


Figure 2.2 Relative biogas yields, depending on temperature and retention time

Many modern biogas plants operate at thermophilic process temperatures as the thermophilic process provides many advantages, compared to mesospheric and psychrophilic processes:

- Effective destruction of pathogens.
- Higher grow rate of methanogenic bacteria at higher temperature.
- Reduced retention time, making the process faster and more efficient.
- Improved digestibility and availability of substrates.
- Better degradation of solid substrates and better substrate utilization.
- Better possibility for separating liquid and solid fractions.

The thermophilic process has also some disadvantages:

- Larger degree of imbalance.
- Larger energy demand due to high temperature.
- Higher risk of ammonia inhibition.

Operation temperature influences the toxicity of ammonia. Ammonia toxicity increases with increasing temperature and can be relieved by decreasing the process temperature. However, when decreasing the temperature to 50°C or below, the growth rate of the thermophilic microorganisms will drop drastically,

and a risk of washout of the microbial population can occur, due to a growth rate lower than the actual HRT (ANGELIDAKI 2004). This means that a well-functioning thermophilic digester can be loaded to a higher degree or operated at a lower HRT than an e.g. mesophilic one because of the growth rates of thermophilic organisms (Figure 2.3). Experience shows that at high loading or at low HRT, a thermophilic operated digester has higher gas yield and higher conversion rates than a mesophilic digester.

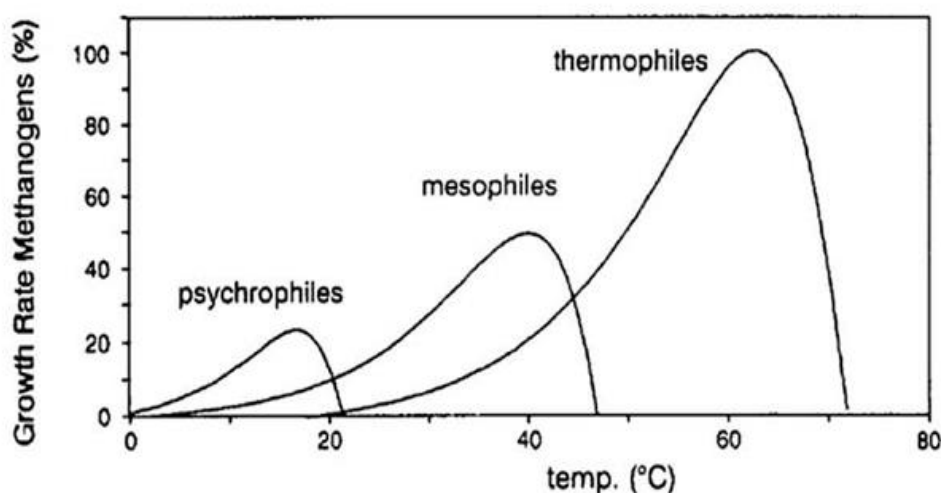


Figure 2.3 Relative growth rates of methanogens

The solubility of various compounds (NH_3 , H_2 , CH_4 , H_2S and VFA) also depends on the temperature (Table 2.2). This can be of great significance for materials which have an inhibiting effect on the process. The viscosity of the AD substrate is inversely proportional to temperature. This means that the substrate is more liquid at high temperatures and the diffusion of dissolved material is thus facilitated. Thermophilic operation temperature results in faster chemical reaction rates, thus better efficiency of methane production, higher solubility and lower viscosity. The higher demand for energy in the thermophilic process is justified by the higher biogas yield. It is important to keep a constant temperature during the digestion process, as temperature changes or fluctuations will affect the biogas production negatively.

Table 2.2 relation between temperature and the solubility in water of some gases

Gas	Temperature	Solubility Mmol /l water	Changed solubility 50c 35c
H ₂	35-50	0.749 – 0.725	3.3%
CO ₂	35-50	26.6 – 19.6	36%
H ₂ S	35-50	82.2 – 62.8	31%
CH ₄	35-50	1.14 – 0.962	19%

Thermophilic bacteria are more sensitive to temperature fluctuation of +/-1°C and require longer time to adapt to a new temperature, in order to reach the maximum methane production. Mesospheric bacteria are less sensitive. Temperature fluctuations of +/- 3°C are tolerated, without significant reductions in methane production. [1]

2.5.2 Volatile fatty acids (VFA)

The stability of the AD process is reflected by the concentration of intermediate products like the VFA. The VFA are intermediate compounds (acetate, propionate, butyrate, lactate), produced during Acid genesis, with a carbon chain of up to six atoms. In most cases, AD process instability will lead to accumulation of VFA inside the digester, which can lead further more to a drop of pH-value. However, the accumulation of VFA will not always be expressed by a drop of pH value, due to the buffer capacity of the digester, through the biomass types contained in it. Animal manure e.g. has a surplus of alkalinity, which means that the VFA accumulation should exceed a certain level, before this can be detected due to significant decrease of pH value. At such point, the VFA concentration in the digester would be so high, that the AD process will be already severely inhibited.

Practical experience shows that two different digesters can behave totally different in respect to the same VFA concentration, so that one and the same concentration of VFA can be optimal for one digester, but inhibitory for the other one. One of the possible explanations can be the fact that the composition of microorganism populations varies from digester to digester. For this reason, and like in the case of pH, the VFA concentration cannot be recommended as a stand-alone process monitoring parameter.

2.5.3 Ammonia

Ammonia (NH₃) is an important compound, with a significant function for the AD process. NH₃ is an important nutrient, serving as a precursor to foodstuffs and fertilizers and is normally encountered as a gas, with the characteristic pungent smell. Proteins are the main source of ammonia for the AD process.

Too high ammonia concentration inside the digester,. This is common to AD of animal slurries, due to their high ammonia concentration, originating from urine. For its inhibitory effect, ammonia concentration should be kept below 80 mg/l. Methanogenic bacteria are especially sensitive to ammonia inhibition. The concentration of free ammonia is direct proportional to temperature, so there is an increased risk of ammonia inhibition of AD processes operated at thermophilic temperatures, compared to mesospheric ones. The free-ammonia concentration is calculated from the equation:

$$[\text{NH}_3] = [\text{T} - \text{NH}_3] / [1 + \text{H}^+/\text{K}_a] \quad (2.3)$$

Where [NH₃] and [T-NH₃] are the free and respectively the total ammonia concentrations, and k_a is the dissociation parameter, with values increasing with temperature. This means that increasing pH and increasing temperature will lead to increased inhibition, as these factors will increase the fraction of free ammonia. When a process is inhibited by ammonia, an increase in the concentration of VFA will lead to a decrease in pH. This will partly counteract the effect of ammonia due to a decrease in the ammonia concentration. [1], [2]

2.5.4 Macro- and micronutrients (trace elements) and toxic compounds

Microelements (trace elements) like iron, nickel, cobalt, selenium, molybdenum or tungsten are equally important for the growth and survival of the AD microorganisms as the macronutrients carbon, nitrogen, phosphor, and Sulphur. The optimal ratio of the macronutrients carbon, nitrogen, phosphor, and Sulphur (C: N: P: S) is considered 600:15:5:1. Insufficient provision of nutrients and trace elements, as well as too high digestibility of the substrate can cause inhibition and disturbances in the AD process.

Another factor, influencing the activity of anaerobic microorganisms, is the presence of toxic compounds. They can be brought into the AD system together with the feedstock or are generated during the process. The application of threshold values for toxic compounds is difficult, on one hand because these kind of materials are often bound by chemical processes and on the other hand because of the capacity of anaerobic microorganisms to adapt, within some limits, to environmental conditions, herewith to the presence of toxic compounds.

2.6 Biogas properties

The energy content of biogas from AD is chemically bounded in methane. The composition and properties of biogas varies to some degree depending on feedstock types, digestion systems, temperature, retention time etc. Table 2.3 contains some average biogas composition values, found in most of the literature. Considering biogas with the standard methane content of 50%, the heating value is of 21 MJ/Nm³, the density is of 1.22 kg/Nm³ and the mass is similar to air (1.29 kg/Nm³).

For liquid manure undergoing fermentation in the mesophilic temperature range (20–40°C), the following approximate heat retention times apply:

- Liquid cow manure: 20–30 days.

- Liquid pig manure: 15–25 days.
- Liquid chicken manure: 20–40 days.
- Animal manure mixed with plant material: 50–80 days.

If the retention time is too short, the bacteria in the digester are “washed out” faster than they can reproduce, so that the fermentation practically comes to a standstill. This problem rarely occurs in agricultural biogas systems.

Table 2.3 Composition of biogas

Compound	Chemical symbol	Content (Vol.-%)
Methane	CH ₄	50-75
Carbon dioxide	CO ₂	25-45
Water vapour	H ₂ O	2 (20°C) -7 (40°C)
Oxygen	O ₂	<2
Nitrogen	N ₂	<2
Ammonia	NH ₃	<1
Hydrogen	H ₂	<1
Hydrogen sulphide	H ₂ S	<1

Main applications of biogas the production of biogas from AD is widely used by modern society for the treatment of livestock manure and slurries. The aim is to produce renewable energy and to improve their fertilizer quality. [1], [2]

2.7 A special application is biogas recovery from existing landfills:-

2.7.1 Agricultural biogas plants:-

The agricultural biogas plants are considered those plants which are processing feedstock of agricultural origin. The most common feedstock types for this kind of plants are animal manure and slurries, vegetable residues and vegetable by

products, dedicated energy crops (DEC), but also various residues from food and fishing industries etc.

The design and technology of biogas plants differ from country to country, depending on climatic conditions and national frameworks (legislation and energy policies), energy availability And affordability. Based on their relative size, function and location, agricultural AD plants can be classified as:

A. Family scale biogas plants:-

In countries like Nepal, China or India operate millions of family scale biogas plants, utilizing very simple technologies. The AD feedstock used in these biogas plants originates. From the household and/or their small farming activity and the produced biogas is used for the family cooking and lighting needs. The digesters are simple, cheap, robust, easy to operate and maintain, and can be constructed with local produced materials. Usually, there are no control instruments and no process heating (psychrophilic or mesospheric operation temperatures), as many of these digesters operate in warmer climates and have long HRT.

B. Farm-scale biogas plants:-

A farm scale biogas plants is named the plant attached to only one farm, digesting the feedstock produced on that farm. Many farm scale plants co-digest also small amounts of methane rich substrates (e.g. oily wastes from fish industries or vegetable oil residues), aiming to increase the biogas yield. It is also possible that a farm scale biogas plant receives and processes animal slurries from one or two neighboring farms (e.g. via pipelines, connecting those farms to the respective AD unit). [1], [2]

The farm scale biogas plants have various sizes, designs and technologies. Some are very small and technologically simple, while others are rather large and complex, similar to the centralized co-digestion plants. Nevertheless, they all have a common principle layout: manure is collected in a pre-storage tank, close to the digester and pumped into the digester, which is a gas-tight tank, made of steel or

concrete, insulated to maintain a constant process temperature. Digesters can be horizontal or vertical, usually with stirring systems, responsible for mixing and homogenizing the substrate, and minimizing risks of swimming-layers and sediment formation. The average HRT is commonly of 20 to 40 days, depending on the type of substrate and digestion temperature. Dig estate is used as fertilizer on the farm and the surplus is sold to plant farms in the nearby area. The produced biogas is used in a gas engine, for electricity and heat production. About 10 to 30% of the produced heat and electricity is used to operate the biogas plant and for domestic needs of the farmer, while the surplus is sold to power companies and respectively to neighboring heat consumers.

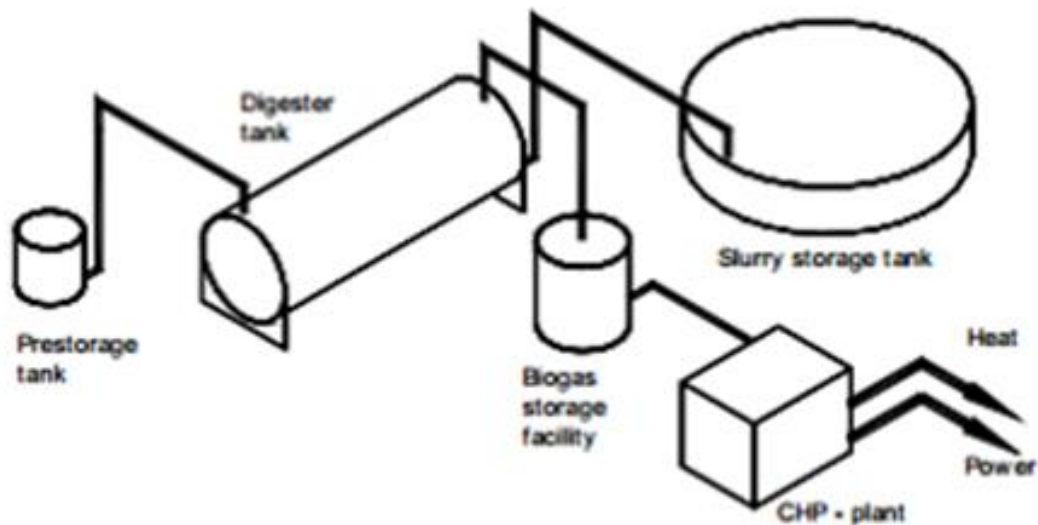


Figure 2.4 schematic representation of a farm scale biogas plant, with horizontal digester of steel

Apart from the digester, equipped with stirring system, the plant can include pre-storage for fresh biomass, storage for digested biomass and for biogas, and even a CHP unit. The digester can also be vertical, with or without conic bottom a so-called 'two-in-one' slurry storage and digester tank, where the digester is build inside the storage tank for dig estate. The two tanks are covered with a gas tight membrane, inflated by the emerging gas production and stirred by electric

propeller. The plant can further more consist of a pre-storage tank for the co-substrate and a CHP-unit.



Figure 2.5 horizontal digester of steel, built in Denmark

In all cases, digestive is integrated in the fertilization plan of the farm, replacing mineral fertilizers, closing the cycle of carbon and nutrient recycling (Figure 2.6). More and more biogas plants are also equipped with installations for separation of digestive in liquid and solid fractions.

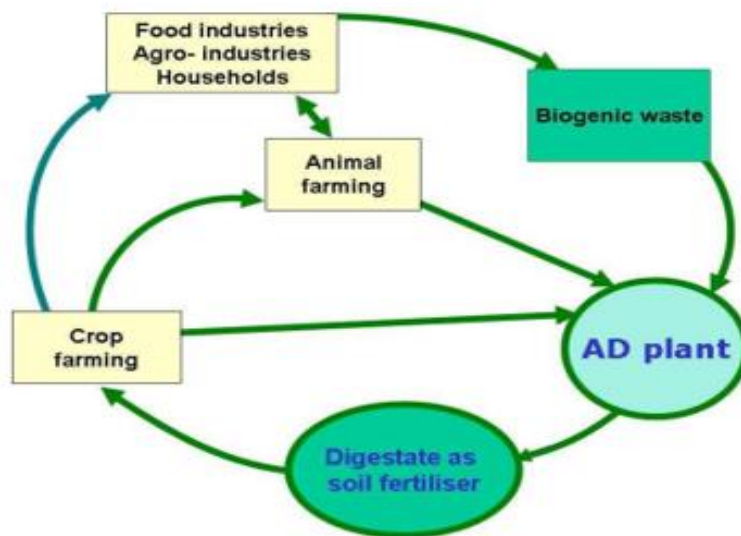


Figure 2.6 schematic representation of the closed cycle of centralized AD

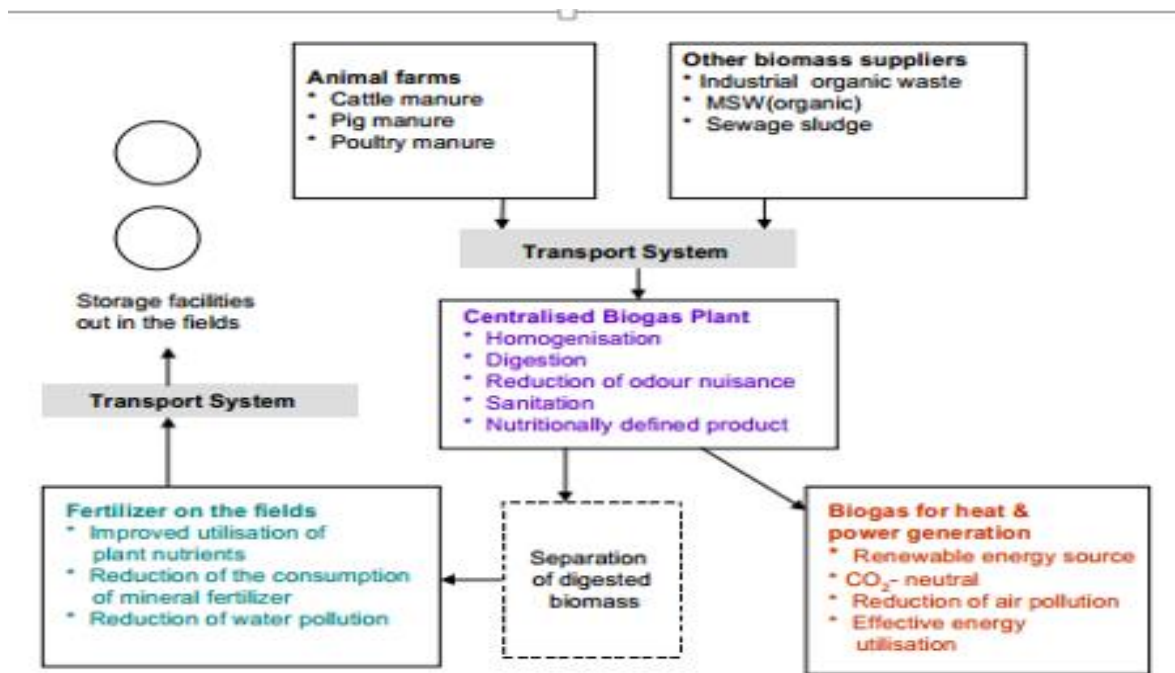


Figure 2.7 the integrated concept of centralized co-digestion plant

2.7.2 Industrial biogas plants:-

Processes are largely used for the treatment of industrial wastes and waste waters for more than a century and AD is today a standard technology for the treatment of various industrial waste waters from food-processing, agro-industries, and pharmaceutical industries.

AD is also applied to pre-treat organic loaded industrial waste waters, before final disposal. Due to recent improvements of treatment technologies, diluted industrial waste waters can also be digested. Europe has a leading position in the world Anaerobic regarding this application of AD. In recent years energy considerations and environmental concerns have further increased the interest in direct anaerobic treatment of organic industrial wastes and the management of organic solid wastes from industry is increasingly controlled by environmental legislations. Industries using AD for wastewater treatment range from:

- **Food processes:** e.g. vegetable canning, milk and cheese manufacture.
- **Beverage industry:** e.g. breweries, soft drinks, distilleries, coffee, fruit juices

- **Industrial products:** e.g. paper and board, rubber, chemicals, starch, pharmaceuticals Industrial biogas plants bring about a number of benefits for the society and the industries involved:

- Added value through nutrient recycling and cost reductions for disposal
- Utilization of biogas to generate process energy
- Improved environmental image of the industries concerned, through environmental friendly treatment of the produced wastes it is expected that the environmental and socio-economic benefits of AD, complemented by higher costs/taxation of other disposal methods, will increase the number of applications of industrial biogas in the future.

2.8 Utilizations of biogas

Biogas has many energy utilizations, depending on the nature of the biogas source and the local demand. Generally, biogas can be used for heat production by direct combustion, electricity production by fuel cells or micro-turbines, CHP generation or as vehicle fuel. [1]

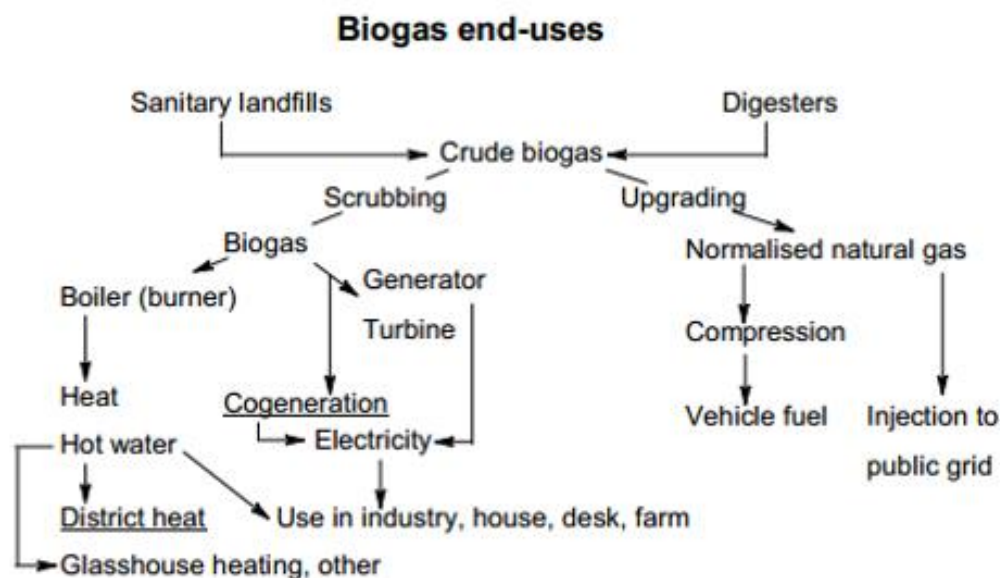


Figure 2.8 over view of biogas utilisation

CHAPTER THREE

BIOGAS HYBRID SYSTEM

3.1 Introduction

Any combination of more than one source of energy is considered a hybrid system. Depending on the lowest cost of the available options, we may consider solar and natural gas, or solar, wind and bio-mass [1], or even solar and oil fired power plants. However, we will limit the definition of hybrid plants to environmentally acceptable solutions. In case of biogas, there can be an argument that we will still Generate carbon dioxide, which is greenhouse gas, and some other emissions. Nonetheless, the impact of locally produced gas is considered as carbon neutral, or at least greenhouse gas neutral. One could also argue that the impact of locally produced bio-gas [2] is less environmentally harmful than the alternative lead-acid

3.2 Biomass CHP technology based on a steam turbine process

Wood-fired combined heat and power production (CHP) The CHP technology based on a steam turbine process represents a field-tested large-scale application ($>2 \text{ M W}_{\text{el}}$) in the field of electricity production from solid biomass. The process of generating electricity from steam comprises following parts: a firing subsystem (biomass combustion), a steam subsystem (boiler and steam delivery system), a steam turbine with electric generator, as well as a feed water and condensate system. In terms of combustion technologies grate firing systems or over a firing thermal capacity of 20-30 MW fluidized bed combustion units are commonly implemented. In the lower power range of steam turbine technologies either still fire tube boilers or already water tube boilers are applied as steam generators. Above a power range of 5 MW_{el} , due to the higher attainable live steam parameters, steam is produced in water tube boilers.

Regarding steam turbine technology backpressure turbines and extraction condensing turbines have to be distinguished. If there is a constant heat demand in form of hot water or low pressure steam all over the year backpressure turbines are used. At projects with the need of uncoupling the electricity and heat production extraction condensing turbines are applied, using the steam which is not or only to a low part required for heat supply in the low pressure part of the turbine to increase electricity production. [3]

3.2.1 Working principle and integration in a biomass CHP plant

The working principle is according to the classical Clausius-Rankine-Process. High temperature, high pressure steam is generated in the boiler and then enters the steam turbine. In the steam turbine, the thermal energy of the steam is converted to mechanical work.

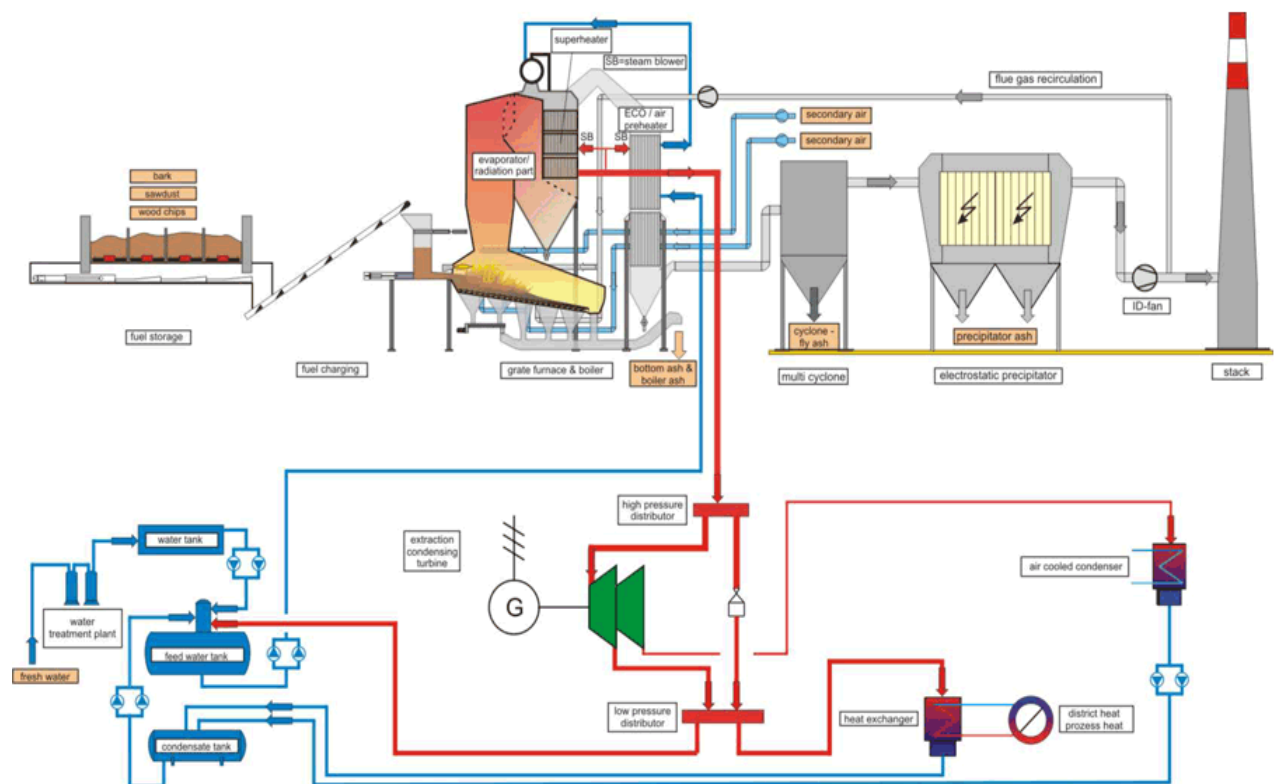


Figure (3.1): illustrating a typical biomass CHP plant based on an extraction condensing turbine process

Low pressure steam exiting the turbine enters the condenser shell and is condensed on the condenser tubes. As the steam is cooled to condensate, the condensate is transported by the boiler feed-water system back to the boiler, where it is used again.

The steam boiler consists of the evaporator unit, the super heater and the economizer which are usually arranged in a four-pass design. In addition, some manufacturers implement an additional combustion air preheated in the flue gas downstream the economizer whereas others use steam or hot water for combustion air preheating. The feed water of the water steam cycle is heated in the feed water economizer which is installed downstream the super heater, to a temperature close to the boiling point. The feed water economizer is the first of three possible heat recovery units (the others are combustion air preheated and condensate preheated) downstream the super heater. In the combustion chamber, the chemically bounded energy of the fuel is released and transferred via boiler and surface of the heat-exchangers to the water steam cycle. The heated water is evaporated in the boiler evaporator and collected in the steam drum. Usually the vertically arranged evaporator tubes also constitute the upper part of the combustion chamber walls. The steam drum is located outside the flue gas flow. From the steam drum the saturated steam is transferred to the super heater. The super heater uses flue-gas at a high temperature level to produce superheated steam. Attention should be paid to high temperature corrosion mechanisms which may require the implementation of a protective evaporator prior to the super heater in order to control the flue gas temperature. After the boiler multi-cyclones and electrostatic precipitators or fabric filters are commonly used to remove dust from the flue-gas. Superheated steam at high pressure and high temperature is ducted via pipes to the steam turbine where it is consumed and depressurized. At the extraction condensing turbine steam is extracted from the turbine at a pressure state which is predetermined by the heat consumers. The main part of this extracted pressure

steam goes to the heating condenser and a smaller part is used to transfer heat to the feed-water. The rest of the steam expands in the low pressure part of the turbine to the condenser pressure state and is then cooled at constant pressure. Depending on the conditions on site dry air-cooled condensers or water cooled condensers are installed.

In general the turbo generator unit includes the model

- steam turbine
- gearbox/generator unit
- lubricating oil system
- control oil system
- measuring and control system

De-ionized water is used for the water steam circuit in order to keep an undisturbed operation. In the water treatment unit solved and dissolved impurities of the natural water must be removed.

Losses in the water-steam circuit caused by blow down and sampling are replenished by de-ionized water from the feed water treatment unit. [2], [3]

3.2.2 Relevant technical data and efficiencies of the steam turbine process

If only chemically untreated wood-like biomass is used, after present state of the art, live steam temperatures to approximately 540°C are achieved. Using waste wood the live steam temperatures must be lowered on approximately 450 °C to avoid increased deposition -und corrosion attack. The attainable electric annual use efficiency (= annual electricity production / annual fuel input based on its net caloric value) depends on the live steam parameters (temperature, pressure) and on the other hand on the necessary temperature level for the process and/or district heat consumers. Electric annual use efficiencies are usually between 18 and 30 %

for biomass CHP plants in the capacity range between 2 and 25 MW_{el}. Steam parameters and electric capacities at steam turbine processes:

- Live steam temperature: 450 – 540 °C
- Live steam pressure: 20 – 100 bar(a)
- Live steam flow rate: 10 – 125 t/h
- Back pressure or extraction steam pressure: 1 – 10 bar
- Exhaust steam pressure: 0,05 – 0,60 bar(a)
- Electric capacity: 2 – 25 MW_{el}
- Electric annual use efficiency: 18 – 30 %

3.3 Biogas and solar hybrid system

The biogas is generated from anaerobic biodegradation of organic materials during the absence of oxygen and the presence of microorganisms. The process includes a series of metabolic reactions among which various groups of microorganisms, executing in three different steps, hydrolysis, liquefaction acid genesis and methanogens. The process produces mainly CH₄, CO₂ and a solid mixture. The biogas generation is developing with the biogas usage. The biogas produced by the industry wastage, agriculture and town is employed to drive the turbine engine to generate electricity. The biogas generation is composed by the biogas pool, desulphurizing tower, special pressure pot, gas engine and generator, which is shown in fig3.2 [3] and fig3.3 the block diagram of the combined PV/T and biogas system is shown below in fig3.3

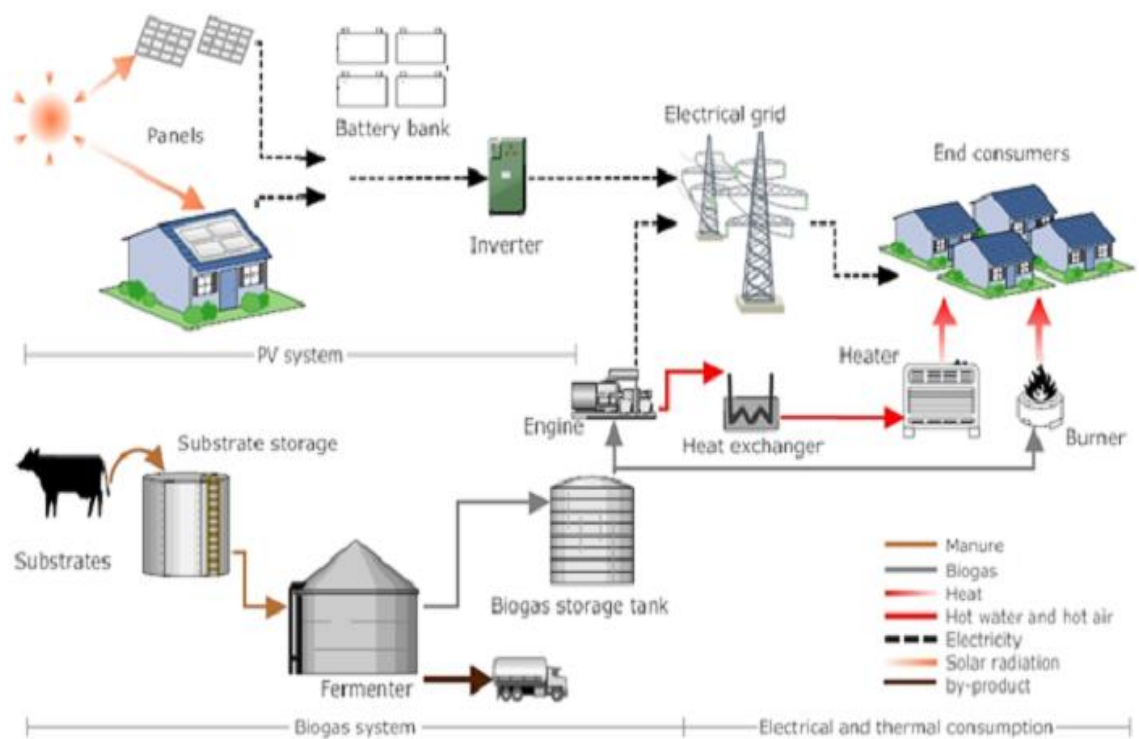


Figure 3.2 biogas-PV hybrid systems

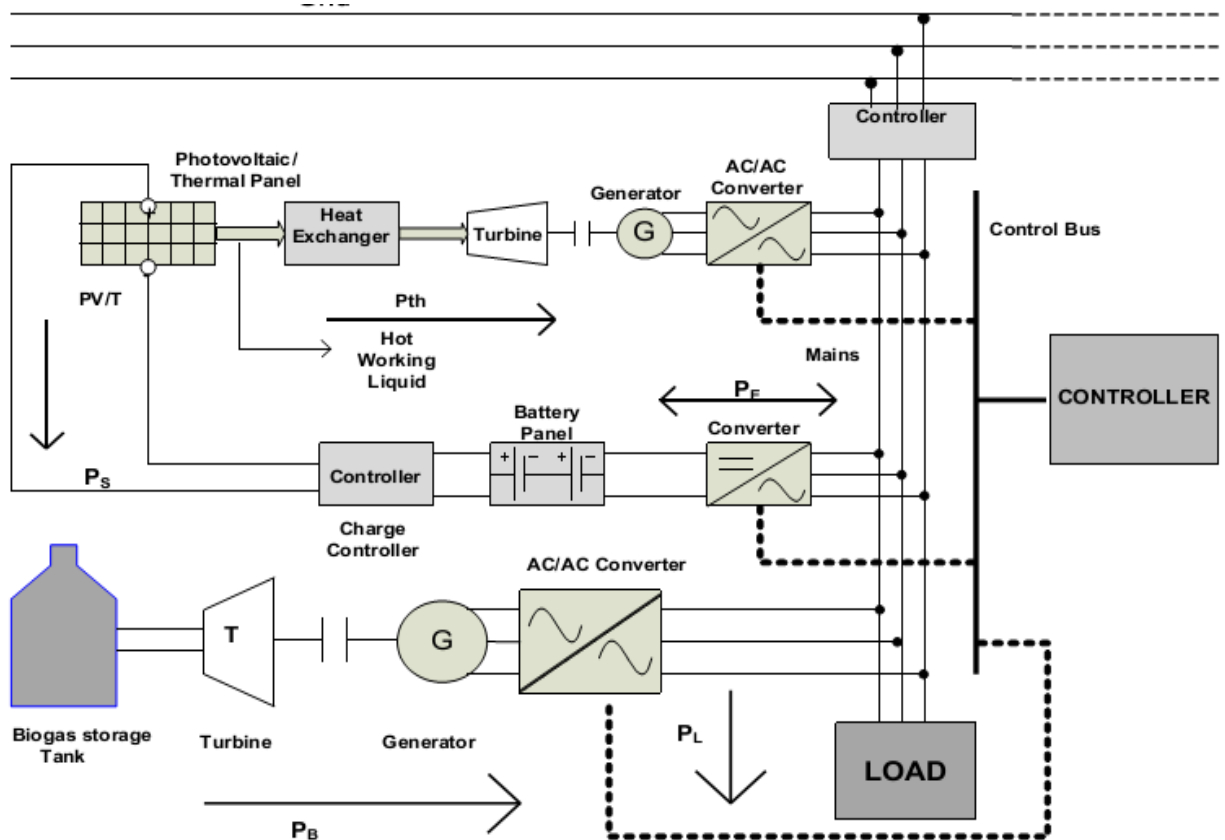


Figure (3.3): PV/T and Biogas DPS

The source of biogas is waste of industries, agriculture and Towns etc. This biogas is fired to drive some generator or turbine [4]. The biogas power generation is controlled power generation mechanism and it can be used to balance the power output from PV/T panels.

3.4 Power flow of the system

The power generated by Photovoltaic panel is DC which is converted to AC through a DC/AC convertor and then supplied to AC bus bar. The current from the Thermal part and Biogas part is AC and supplied to AC bus bar through an AC/AC convertor as shown below. Now there exist three relationships between power generated and power supplied to the load.

3.5 Bioethanol

The principle fuel used as a petrol substitute for road transport vehicles is bioethanol. Bioethanol fuel is mainly produced by the sugar fermentation process, although it can also be manufactured by the chemical process of reacting ethylene with steam. The main sources of sugar required to produce ethanol come from fuel or energy crops. These crops are grown specifically for energy use and include corn, maize and wheat crops, waste straw, willow and poplar trees, sawdust, reed canary grass, cord grasses, Jerusalem artichoke, miscanthus and sorghum plants. There is also ongoing research and development into the use of municipal solid wastes to produce ethanol fuel.

Ethanol or ethyl alcohol (C_2H_5OH) is a clear colorless liquid, it is biodegradable, low in toxicity and causes little environmental pollution if spilt. Ethanol burns to produce carbon dioxide and water. Ethanol is a high octane fuel and has replaced lead as an octane enhancer in petrol. By blending ethanol with gasoline we can also oxygenate the fuel mixture so it burns more completely and reduces polluting emissions. Ethanol fuel blends are widely sold in the United States. The most common blend is 10% ethanol and 90% petrol (E10). Vehicle engines require no

modifications to run on E10 and vehicle warranties are unaffected also. Only flexible fuel vehicles can run on up to 85% ethanol and 15% petrol blends (E85). [3], [4]

3.5.1 The benefits of bioethanol

Bioethanol has a number of advantages over conventional fuels. It comes from a renewable resource i.e. crops and not from a finite resource and the crops it derives from can grow well in the UK (like cereals, sugar beet and maize). Another benefit over fossil fuels is the greenhouse gas emissions. The road transport network accounts for 22% (www.foodfen.org.uk) of all greenhouse gas emissions and through the use of bioethanol, some of these emissions will be reduced as the fuel crops absorb the CO₂ they emit through growing. Also, blending bioethanol with petrol will help extend the life of the UK's diminishing oil supplies and ensure greater fuel security, avoiding heavy reliance on oil producing nations. By encouraging bioethanol's use, the rural economy would also receive a boost from growing the necessary crops. Bioethanol is also biodegradable and far less toxic than fossil fuels. In addition, by using bioethanol in older engines can help reduce the amount of carbon monoxide produced by the vehicle thus improving air quality. Another advantage of bioethanol is the ease with which it can be easily integrated into the existing road transport fuel system. In quantities up to 5%, bioethanol can be blended with conventional fuel without the need of engine modifications. Bioethanol is produced using familiar methods, such as fermentation, and it can be distributed using the same petrol forecourts and transportation systems as before. [3]

3.5.2 Bioethanol production

Ethanol can be produced from biomass by the hydrolysis and sugar fermentation processes. Biomass wastes contain a complex mixture of carbohydrate polymers from the plant cell walls known as cellulose, hemicellulose and lignin. In order

to produce sugars from the biomass, the biomass is pre-treated with acids or enzymes in order to reduce the size of the feedstock and to open up the plant structure. The cellulose and the hemi cellulose portions are broken down (hydrolyzed) by enzymes or dilute acids into sucrose sugar that is then fermented into ethanol. The lignin which is also present in the biomass is normally used as a fuel for the ethanol production plants boilers. There are three principle methods of extracting sugars from biomass. These are concentrated acid hydrolysis, dilute acid hydrolysis and enzymatic hydrolysis.

I. Concentrated Acid Hydrolysis Process

The Arkanol process works by adding 70-77% sulphuric acid to the biomass that has been dried to a 10% moisture content. The acid is added in the ratio of 1.25 acid to 1 biomass and the temperature is controlled to 50C. Water is then added to dilute the acid to 20-30% and the mixture is again heated to 100C for 1 hour. The gel produced from this mixture is then pressed to release an acid sugar mixture and a chromatographic column is used to separate the acid and sugar mixture.

II. Dilute Acid Hydrolysis

The dilute acid hydrolysis process is one of the oldest, simplest and most efficient methods of producing ethanol from biomass. Dilute acid is used to hydrolyze the biomass to sucrose. The first stage uses 0.7% sulphuric acid at 190C to hydrolyze the hemi cellulose present in the biomass. The second stage is optimized to yield the more resistant cellulose fraction. This is achieved by using 0.4% sulphuric acid at 215C. The liquid hydrolates are then neutralized and recovered from the process.

III. Enzymatic Hydrolysis

Instead of using acid to hydrolyze the biomass into sucrose, we can use enzymes to break down the biomass in a similar way. However this process is very expensive and is still in its early stages of development.

IV. Wet Milling Processes

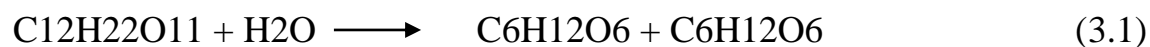
Corn can be processed into ethanol by either the dry milling or the wet milling process. In the wet milling process, the corn kernel is steeped in warm water, this helps to break down the proteins and release the starch present in the corn and helps to soften the kernel for the milling process. The corn is then milled to produce germ, fibre and starch products. The germ is extracted to produce corn oil and the starch fraction undergoes centrifugation and saccharification to produce gluten wet cake. The ethanol is then extracted by the distillation process. The wet milling process is normally used in factories producing several hundred million gallons of ethanol every Year.

V. Dry Milling Process

The dry milling process involves cleaning and breaking down the corn kernel into fine particles using a hammer mill process. This creates a powder with a course flour type consistency. The powder contains the corn germ, starch and fibre. In order to produce a sugar solution the mixture is then hydrolyzed or broken down into sucrose sugars using enzymes or a dilute acid. The mixture is then cooled and yeast is added in order to ferment the mixture into ethanol. The dry milling process is normally used in factories producing less than 50 million gallons of ethanol every Year.

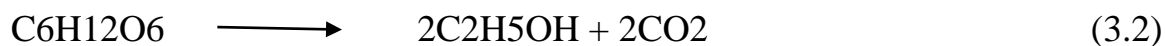
VI. Sugar Fermentation Process

The hydrolysis process breaks down the cellulosic part of the biomass or corn into sugar solutions that can then be fermented into ethanol. Yeast is added to the solution, which is then heated. The yeast contains an enzyme called inverses, which acts as a catalyst and helps to convert the sucrose sugars into glucose and fructose (both $C_6H_{12}O_6$) The chemical reaction is shown below:



The fructose and glucose sugars then react with another enzyme called zymase, which is also contained in the yeast to produce ethanol and carbon dioxide.

The chemical reaction is shown below:



The fermentation process takes around three days to complete and is carried out at a temperature of between 25°C and 30°C.

VII. Fractional Distillation Process

The ethanol, which is produced from the fermentation process, still contains a significant quantity of water, which must be removed. This is achieved by using the fractional distillation process. The distillation process works by boiling the water and ethanol mixture. Since ethanol has a lower boiling point (78.3°C) compared to that of water (100°C), the ethanol turns into the vapour state before the water and can be condensed and separate. [2],[4]

3.6 Biodiesel

Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Using biodiesel as a vehicle fuel increases energy security, improves public health and the environment, and provides safety benefits.

3.6.1 Energy security and balance

The United States imports about half of its petroleum, two-thirds of which is used to fuel vehicles in the form of gasoline and diesel. Depending heavily on foreign petroleum supplies puts the United States at risk for trade deficits, supply disruption, and price changes. Biodiesel can be produced in the U.S. and used in conventional diesel engines, directly substituting for or extending supplies of traditional petroleum diesel. [3]

3.6.2 Air quality

Compared with using petroleum diesel, using biodiesel in a conventional petroleum diesel engine substantially reduces tailpipe emissions of unburned hydrocarbons (HC), carbon monoxide (CO), sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter (PM). The reductions increase as the amount of biodiesel blended into diesel fuel

increases for engines manufactured before 2010. Engines manufactured in 2010 and later have to meet the same emissions standards, whether running on biodiesel, diesel, or even natural gas. Selective catalytic reduction (SCR) technology, which reduces nitrogen oxide (NOx) emissions to near zero levels, makes this possible. For these new technology engines, the emissions from diesel fuel are comparable to those from biodiesel and are very, very low. These new technology engines are some of the cleanest engines on the road. B100 provides the best emission reductions, but lower-level blends also provide benefits. B20 has been shown to reduce PM emissions 10%, CO 11%, and unburned HC 21% (see graph) in older engines. Learn more about Biodiesel Emissions.

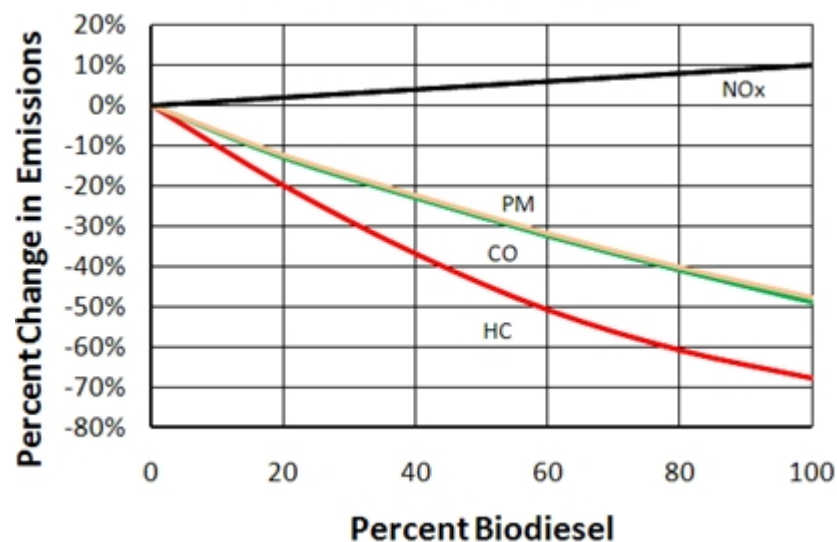


Figure 3.4 average emission impact of biodiesel for heavy-duty highway engine

Using biodiesel reduces greenhouse gas emissions because carbon dioxide released from biodiesel combustion is offset by the carbon dioxide sequestered while growing the soybeans or other feedstock. B100 use reduces carbon dioxide emissions by more than 75% compared with petroleum diesel. Using B20 reduces carbon dioxide emissions by 15%. Greenhouse gas and air-quality benefits of biodiesel are roughly commensurate with the blend. B20 use provides about 20%

of the benefit of B100 use. B100 use could increase nitrogen oxides emissions, although it greatly reduces other emissions.

3.6.3 Engine operation

Biodiesel improves fuel lubricity and raises the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts from wearing prematurely. One unintended side effect of the federal regulations, which have gradually reduced allowable fuel sulfur to only 15 ppm and lowered aromatics content, has been to reduce the lubricity of petroleum diesel. To address this, the ASTM D975 diesel fuel specification was modified to add a lubricity requirement (a maximum wear scar diameter on the high-frequency reciprocating rig [HFRR] test of 520 microns). Biodiesel can increase lubricity to diesel fuels at blend levels as low as 1%. Before using biodiesel, be sure to check your engine warranty to ensure that higher-level blends of this alternative fuel don't void or affect it. High-level biodiesel blends can also have a solvency effect in engines that previously used petroleum diesel.

3.6.4 Safety

Biodiesel is nontoxic. It causes far less damage than petroleum diesel if spilled or released to the environment. It is safer than petroleum diesel because it is less combustible. The flashpoint for biodiesel is higher than 130°C, compared with about 52°C for petroleum diesel. Biodiesel is safe to handle, store, and transport. [4],[3]

CHAPTER FOUR

UNIT DESIGN AND ANALYSIS OPERATION OF BIO-DIESEL GENERATOR

4.1 Biogas digesters

For the production of biogas, organic material, such as animal and plant waste is placed along with water into an oxygen free tank, or in some cases plastic membrane for digestion which is known as the digester. The organic matter is fed into the vessel and the resulting gas is outlet through a pipe that inlets above the waste liquid levels in the tank. Similar mechanisms are achieved using plastic membranes, which are contained in secure enclosures in the ground. Various digester designs exist.

4.1.1 Types of biogas plants

The three main types of simple biogas plants are:

i. Balloon plants

The balloon plant consists of a digester bag (e.g. PVC) in the upper part of which the gas is stored. The inlet and outlet are attached directly to the plastic skin of the balloon. The desired gas pressure is attained through the elasticity of the balloon and by added weights placed on it.

ii. Fixed-dome plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

iii. Floating-drum plants

Floating-drum plants consist of an underground digester and a moving gas-holder. The gas holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content. [4], [5]

4.1.2 Design of biogas station

In this section the procedure for building 5KW biogas station is investigated. According the required volume of biogas to produce 1KW/h is 0.7m^3 . Based on this information the station is designed as follow:

$$1\text{KW/h} \rightarrow 0.7\text{ m}^3$$

$$5\text{KW/h} \rightarrow x$$

$$\text{Therefore } x = 3.5\text{ m}^3$$

$$\text{The production of gas per day} = 3.5 * 24 = 84\text{ m}^3/\text{day}$$

$$\text{The rate of gas production in } 25^\circ\text{C} = 0.3$$

$$\text{Effective size of fermented} = 84/0.3 = 280\text{ m}^3$$

$$\text{Residence time} = 40\text{ day}$$

$$\text{The size of the daily diet} = 280/40 = 7000\text{ liter} = 7\text{ m}^3$$

$$\text{Assume the concentration dietary dry matter} = 8\%$$

$$\text{Dry weight} = (7000 * 8)/100 = 560\text{ Kg}$$

$$\text{For } 1\text{ m}^3\text{ of Effective size of fermented required } 0.238\text{ m}^3\text{ of size of gas tank}$$

$$\text{Therefore } 280\text{ m}^3\text{ required } 67.12\text{ m}^3$$

$$\text{Therefore size of gas tank} = 67.12\text{ m}^3$$

$$\text{The total size of tank} = 280 + 67.12 = 347.12\text{ m}^3$$

4.2 Biogas purification processes

Biogas enrichment processes are the methods of removing unwanted gases from biogas to increase its calorific value. The presence of incombustible gases like CO₂ and hydrogen sulphide H₂S and water vapor reduce the calorific value of biogas and make it uneconomical to compress and transport to longer distances. The removal of CO₂ and H₂S increases the percentage of methane in the biogas thus enriching its content up to the natural gas level.

4.2.1 Methods for scrubbing carbon dioxide

The following are methods for removing carbon dioxide (CO₂) from biogas. Most of these methods are processes being used for removing CO₂ from natural gas in petrochemical industries. These may include physical or chemical absorption, adsorption on a solid surface, membrane separation, cryogenic separation and chemical conversion.

A. Physical or chemical absorption (water scrubbing)

Physical/chemical absorption method is generally applied for biogas scrubbing as it is effective even at low flow rates that the biogas plants normally operate. Also the method is less complicated, requires fewer infrastructures and is cost effective. The cheapest method makes use of pressurized water as an absorbent. When water scrubbing is used for CO₂ removal, biogas is pressurized, typically from 1.03 M Pa to 2.07 M Pa with a two-stage compressor, and then introduced into the bottom of a tall vertical column. The raw biogas is introduced at the bottom of the column and flows upward, while fresh water is introduced at the top of the column, flowing downward over a packed bed. The packed bed (typically a high-surface-area plastic media) allows for efficient contact between the water and gas phases in a countercurrent absorption regime. Water often pools at the bottom of the contact column and the biogas first passes through this water layer in the form of bubbles. The CO₂-saturated water is continuously withdrawn from the bottom of the column and the cleaned gas exits from the top. A purity of about 95% methane

can be readily achieved with minimal operator supervision in a single pass column. After scrubbing, the water can be regenerated (i.e., stripped of CO_2 by contacting with air at atmospheric pressures, either in a packed bed column similar to the one used for absorption, or in a passive system such as a stock pond).

B. Chemical absorption

This method follows the principle of absorption of CO_2 gas using suitable bases to result an acid base neutralization reaction thereby, absorbing and reducing the CO_2 content in biogas. Savory and Curzon [suggested the use of NaOH , KOH and $\text{Ca}(\text{OH})_2$ in the chemical scrubbing of biogas. The absorption of CO_2 in alkaline solution is assisted by agitation. The rate of absorption is also increased by the concentration of the solution. The rate of absorption is most rapid with NaOH .

C. Cryogenic separation

Carbon dioxide CO_2 , Methane CH_4 , and contaminants all liquefy at very different temperature pressure domains, it is therefore possible to produce CH_4 from biogas by cooling and compressing the biogas to liquefy CO_2 which is then easily separated from the remaining gas. The extracted CO_2 also can be used as a solvent to remove impurities from the gas. In a cryogenic method, crude biogas is compressed to approximately 80 bar. The compression is made in multiple stages with inter-cooling. The compressed gas is dried to avoid freezing during the cooling process. The biogas is cooled with chillers and heat exchangers -45°C , condensed CO_2 is removed in a separator. The CO_2 is processed further to recover dissolved methane, which is recycled to the gas inlet. This process bring about the recovery of pure component in the form of a liquid, which can then be transported conveniently and more than 97% pure methane is obtained. [4]

4.2.2 Methods for removing hydrogen sulphide

The concentration of H_2S in biogas generated from animal manure typically ranges between 1000 and 2400 ppm, depending mainly on the sulphate content of

the local water The presence of hydrogen sulphide in biogas varies with the feedstock and has to be removed in order to avoid corrosion in compressors, gas storage tanks and engines. H_2S is poisonous and corrosive as well as environmentally hazardous since it is converted to Sulphur dioxide by combustion. It also contaminates the upgrading process. H_2S can be removed either in the digester, from the crude biogas or in upgrading process. The methods for removing hydrogen sulphide have been high-lighted. They are as follows:

(1) Dry oxidation process.

(2) Liquid phase oxidation process.

a) Dry oxidation process

It is a method for removing of H_2S from gas streams by converting it either into Sulphur or oxides of Sulphur. This process is used where the Sulphur content of gas is relatively low and high purities are required. Some of these methods are described below.

i. Introduction of air/oxygen into the biogas system.

A small amount of oxygen (2–6%) is introduced in the biogas system by using an air pump. As a result, sulphide in the biogas is oxidized into Sulphur and H_2S concentration is thereby lowered.



This method is simple and cost effective. No special chemicals or equipment's are required. Depending on the temperature, the reaction time and place where the air is added, the H_2S concentration can be reduced by 95% to less than 50 p pm. However, care should be taken to avoid overdosing of air, as biogas in air is explosive depending on the methane content.

ii. Adsorption using iron oxide

H_2S reacts with iron hydro-oxides or oxides to form iron sulphide. The biogas is passed through iron oxide pellets, to remove H_2S . When the pellets are completely covered with Sulphur, these are removed from the tube for the regeneration of

Sulphur. It is a simple method but a lot of heat is released during regeneration. Also the dust packing contains a toxic component and the method is sensitive to high water content of biogas. This method was used by Baron. Scrub hydrogen sulphide.

b) Liquid phase oxidation process

This process is primarily used for the treatment of gases containing relatively low concentration of H_2S . It may be either:-

(a) Physical absorption process.

(b) Chemical absorption process.

In physical absorption process the H_2S can be absorbed by the solvents. One of the solvents is water. But the consumption of water is very high for absorption of small amount of H_2S . If some chemicals like NaOH are added to water, the absorption process is enhanced. It forms sodium sulphide or sodium hydrosulphide, which is not regenerated and poses problems of disposal. However in practice, the process is not regenerative and is thus prohibitively expensive. For this reason many choose to rely on water alone to absorb the H_2S .

4.2.3 Elimination of water vapor

Biogas from digesters is normally collected from headspace above a liquid surface or very moist substrate, as a result of this, the gas is usually saturated with water vapour. The amount of saturated water vapour in a gas depends on temperature and pressure. Biogas typically contains 10% water vapour. Various methods can be employed to eliminate this. A moisture trap may be constructed by placing a jar of water is placed outside the pit and a gas pipe of at least 20 cm long is put into it in downward projection. Any moisture condensing in the pipe flows into the jar instead of collecting in the pipe and obstructing the passage of gas. Water then overflows and is lost in the ground. The simplest method to remove condensed water is to install horizontal pipe runs with a slope of 1:100. A drip trap or condensate drain can then be located at all low points in the piping to

remove condensation. However, this will only remove water vapour that condenses in the piping. Vijay et al used a set of three filters (Pre-filter, Micro-filter and Sub-Micro filter) in the Galvanized Iron pipeline connected with the storage pressure vessel (containing enriched biogas) and the three stage compressor. [4], [5]

4.3 Storage of biogas

Biogas is usually produced in the farm where there is availability of feedstock (usually dairy manure). It is often necessary to store the biogas produced because most farms will produce more biogas than they can use on-site. It can be stored for later on-site usage or for transportation to off-site distribution points or systems. Storage of biogas is very important because methane is a very combustible gas and the risk of storage at high pressure is also high. Biogas must be stored in vessels that are compatible with the Pressure of the gas. Most commonly used biogas storage systems can be seen in FIGURE 4.1.

4.3.1 Low pressure storage of biogas

Floating gas holders on the digester form a low-pressure storage option for biogas systems. Commonly used storage options for biogas Floating gas holders can be made of steel, fiber glass, or a flexible fabric. The least expensive and most trouble-free gas holder is the flexible inflatable fabric top, as it does not react with the H_2S in the biogas and is integral to the digester.



Figure 4.1 illustrate Storage of biogas

Table 4.1 biogas pressure storage

Pressure	Storage device	Material
Low(0.138-0.414bar)	Water sealed gas holder	Steel
Low	Gas bag	Rubber ,plastic,vinyl
Medium(1.05-1.97bar)	Propane or butane tank	Steel
High(200bar)	Commercial gas cylinders	Alloy

4.3.2 Medium-pressure storage of cleaned biogas

Biogas can also be stored at medium pressure 13.79 KPa. It is however necessary to first clean the biogas to remove H_2S in order to prevent corrosion of the tank components and to ensure safe operation. approximately 10% of the energy content of the stored biogas is usually needed for compression of biogas.

4.3.3 High-pressure storage of biogas

There is the need to enrich/clean biogas before it can be stored at high pressure. Enriched biogas is often called bio methane and has a higher calorific value than biogas and can be stored as compressed Biomethane to save space. Gas scrubbing is even more important at high pressures because impurities such as H_2S and water are very likely to condense and cause corrosion. The gas is stored in steel cylinders such as those typically used for storage of other commercial gases. Storage facilities must be adequately fitted with safety devices such as rupture disks and pressure relief valves. [4], [5]

4.4 Components of a Biogas System

The main components of biogas system are:

- Manure Collection
- Anaerobic Digester
- Effluent Storage
- Biogas Handling
- Biogas Use

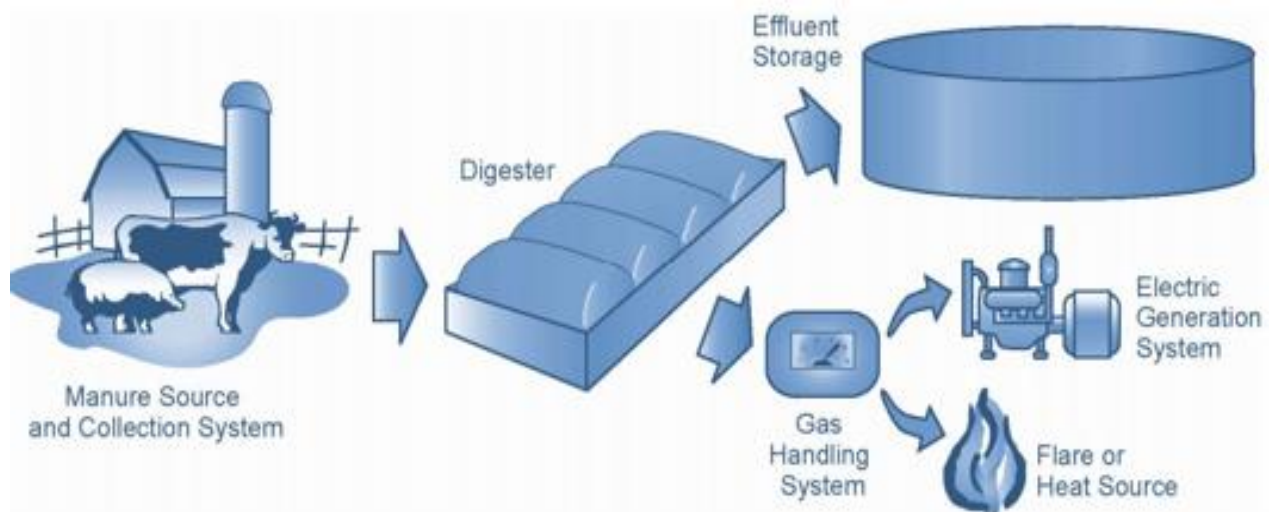


Figure (4.2): Components of a Biogas System

Biogas Use for Electricity– Internal combustion engines, micro turbines, fuel cells– For on-farm use and/or sale to grid. Co-generation (combined heat and power) – Capture heat from engine for electricity generation to warm digester– Could provide heat, hot water or steam for farm or neighboring operations when heat available exceeds the needs of the digester

4.4.1 Manure Collection

Shows the process of manure collection



Figure (4.3): illustrate Manure Collection

4.4.2 Anaerobic Digester

The anaerobic digester is designed to produce 1KW/h with total volume of 0.7m³.

4.4.3 Biogas Handling

Handling system moves biogas from the digester to energy end use Includes piping, pump or blower, gas meter, pressure regulator, and condensate. Drains; maybe gas scrubber. Biogas builds pressure inside the digester – it's removed by putting a slight vacuum on the collection pipe from the digester.



Figure (4.4): illustrate Anaerobic Digester



Figure (4.5): illustrate Biogas Handling

4.5 Experimental apparatus

The specific type of engine used in this project kopta diesel engine. Setup of the experimental engine is illustrated in Fig. 4.6 and its specifications are listed in Table 4.2. The test engine was completed with its own cooling system. There was no modification of the engine, apart from installing a gas mixer upstream of the air inlet duct. The test engine was coupled to an alternator acting as a variable load system. The dynamometer used was an air-cooled, eddy current type. Various instruments and gauges were employed to obtain different measurements. The engine speed was measured by adjusted frequency. Biogas used in the tests was supplied from a local digester. It was stored and compressed to about 1 bar in a closed, collapsible rubber dome from where it was fed to the engine intake port. Prior to entering the engine, biogas was passed through a condensation trap and a gas treatment unit to remove moisture and react with traces amounts of sulfur compounds present in biogas.

TABLE (4.2): AC SYNCHRONOUS GENERATOR SPECIFICATION

Type	ST-5	NO.	50202185
POWER	5 KW	COSØ	1.0
VOLTAGE	220 V	EXIT.VOLT.	49 V
CURRENT	21.8 A	EXIT.URR.	2.6 A
FREQUNCY	50 HZ	INS.CL.	B
SPEED	1500 RPM	RATE PHASE	1 PHASE

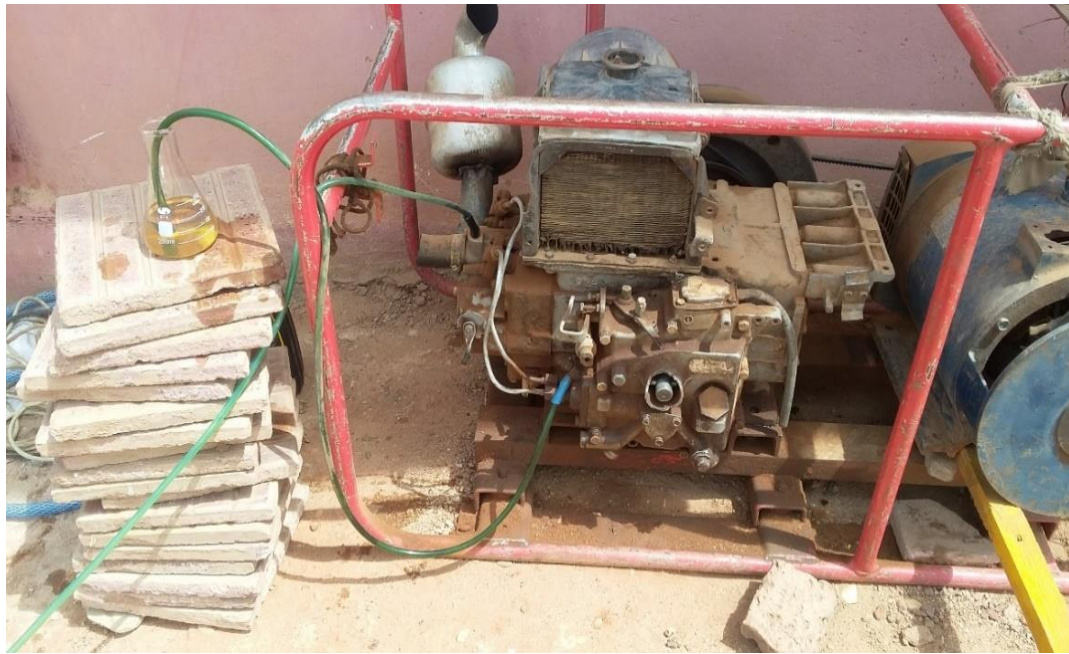


Figure. 4.6 Setup of the engine test rig

4.6 Results

After switching the engine the engine speed was measured by adjusted frequency at 51 HZ and voltage at 220 v show in figure (4.7) after loaded it by 1.2 kw the voltage reduced to 200 v and frequency reduced to 50 HZ because the AVR not available to compensate the voltage drop by increasing excitation current we took this result by using 200 v.



Figure. 4.7 Setup of the HZ meter and voltmeter

The figure below illustrate relation between time and consumption of diesel

In two case when we operate the engine by pure diesel and when we operate by mix of diesel and biogas.

To calculate the volume of gas consumption we calculate the volume of storage space

$$\text{Volume} = \pi * r^2 * h$$

$$V = \pi * 0.27^2 * 0.3 = \underline{\underline{0.068 \text{ m}^3}}$$

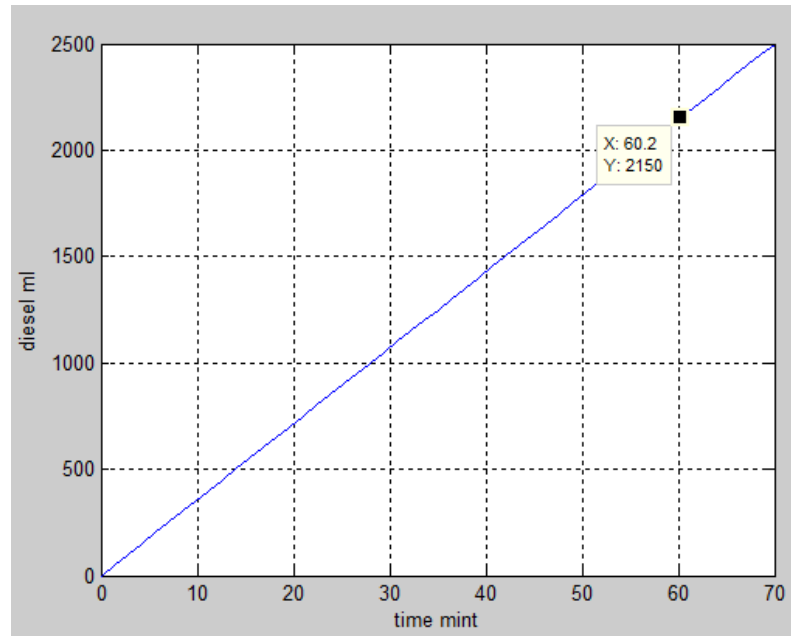


Figure 4.8 illustrate relation between time and consumption of diesel when used pure diesel

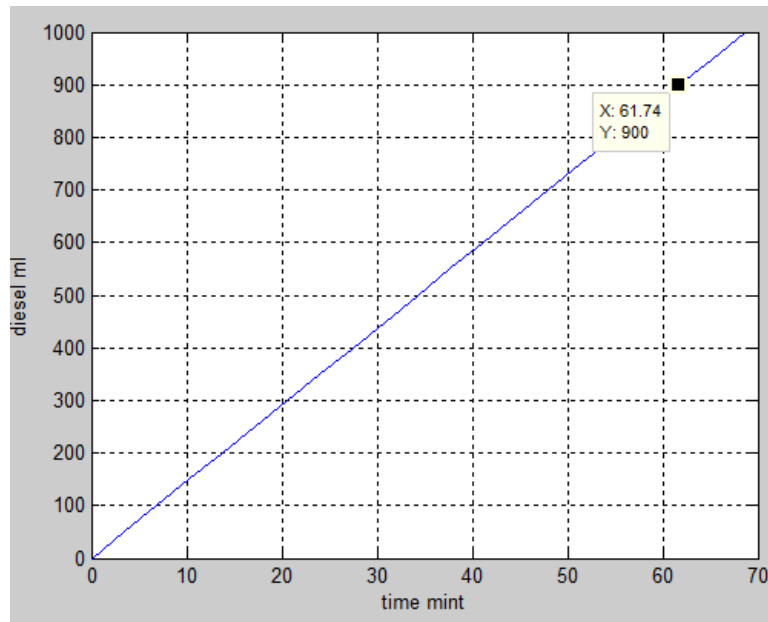


Figure 4.9 illustrate relation between time and consumption of diesel when used mix of diesel and bio gas

CHAPTRE FIVE

CONCULOTION AND RECOMMENDATION

5.1 Conclusion

The biogas from renewable energy sources and environmentally friendly as it can be used to generation of electricity for the pastoral and rural areas and have lot of benefit. In this research was design a small unit to study the productivity of gas from the local waste .gas production three times from manure of cows and when that increased temperature gas was the best production.

The maintenance and modification of the engine done to operate by fuel and gas by mixer fuel and gas inside the combustion chamber.

As there was an attempt to gas purification by sodium hydroxide to purified from impurities and try to compress and store the gas cylinder.

After the experiment we find that the possibility of saving the amount of fuel when the use of gas to generate and reduces the cost of production and also the remnants of AD process is a good fertilizer for agriculture.

5.2 Recommendations

- 1- Built a unit for gas purification.
- 2- Provide pressure for gas to store more quantities.
- 4- Gas analysis to find out its component and real ratio.

REFERENCES:

- [1] Teodorita Al Seadi, Dominik Rutz, Heinz Prassl, Michael Köttner, Tobias Finsterwalder, Silke Volk, Rainer Janssen , “Biogas HANDBOOK” ISBN 978-87-992962-0-0 , Teodorita Al Seadi October 2008
- [2] R. J. Citole, S. Lansing and J. F. Martin, "Energy analysis of biogas production and electricity generation from small-scale agricultural digesters," Ecological Engineering, no. 37, pp. 1681-1691, 2011.
- [3] Z. Yanning¹, K. Longinus, C. Binging; “Simulation of Biogas Generation” Proceedings of IEEE T&D Asia conference, 2009.
- [4] M.A. Ahmed, L. Alonso, J.M.Palacios,C. Cilleruelo, J.C. Abanades, Structural changes in zinc ferrites as regenerable sorbents for hot coal gas desulphur-ization, Solid State Ionics 138 (2000) 51–62.

[5] I.A.A.C. Esteves, M.S.S. Lopes, P.M.C. Nunes, J.P.B. Mota, Adsorption of natural gas and biogas components on activated carbon, Separation and Purification Technology 62 (2008) 281–296

APPENDICES:-

MATLAB PROGRAM TO PLOT RELATION BETWEEN TIME AND COMPSUMTION OF DIESEAL

FIGURE 1

```
Clc
t=0:1.4:70; % TIME MINT
y=50;
x=0:50:2500; % VOLUME OF DESEIL COMSPTION
Plot (t, x)
Grid
Xlabel ('time mint')
Ylabel ('diesel ml')
```

FIGURE 2

```
Clc
```

```

t=0:3.43:70; % TIME MINT
y=50;
x=0:50:1000; % VALUME OF DESEIL COMSPTION
Plot (t, x)
Grid
Xlabel ('time mint')
Ylabel ('diesel ml')

```



AVR port to regulate voltage and exitation for generator



Generator operate by biogas and diesel