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Can rural Gaza Strip be both biogas “self-sufficient” and organic waste and wastewater problem free?

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Title

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Abstract

The rural areas in the Gaza Strip suffer from the problem of sanitation and organic waste as well as electricity and cooking fuel. In this thesis, the biogas plant was designed to solve those problems based on the fixed dome plant design as shown in Figure 3 and 4. Therefore, the efficiency and selectivity was good for biogas plant which is easy for the local people disposal of organic waste and wastewater as well as self-sufficiency of biogas for cooking and electricity for the family. The sediments from the biogas plant are also used as fertilizers in agriculture. Thus it is possible to know the amount of biogas production, the cost of biogas, the amount of fertilizer, the cost of fertilizers and the amount of disposal of organic waste and wastewater. The calculation shows that the size of digester which is equal to 12 cubic meters as shown in figure 4. The construction is cost of \$ 930 as shown in Table 2. Through the results will be disposed of organic waste, wastewater and manure are about 48 kilograms per day for the family. The Biogas is produced 0.5 tons of biogas is estimated about \$ 100 in rural areas in the Gaza Strip. It is also produced fertilizers equivalent of \$ 113 per month. So the results and calculations are clear that the rural family is self-sufficient of biogas, the dispose of organic waste and wastewater and agricultural growth by the fertilizers from the biogas plant.

Keywords

Sustainable Development, Renewable Energy, Waste to Energy, Wastewater treatment, Environment, Ecosystems, Energy sector, Household Biogas Plants.

Table of content

Contents

Abstract.....	2
Acknowledgements.....	5
List of Tables	6
List of Figures	7
1. Introduction	8
1.1. Objectives	9
1.2. Methodology	9
2. Background	9
2.1. Location and condition	9
2.2. Climate of the Gaza Strip	10
2.3. Water pollution in the Gaza Strip	11
2.4. Environmental pollution in the Gaza strip	12
2.4.1 Solid waste	13
2.4.2 Wastewater.....	14
3. Why is biogas	16
3.1. Biogas composition.....	17
3.2. The benefits of biogas	17
3.2.1. Disposal of organic waste and wastewater.....	17
3.2.2. Provides renewable energy	17
3.2.3. Production of organic fertilizer	17
3.2.4. Improve sanitation.....	17
3.2.5. Create jobs in rural areas	18
3.2.6. The production of biogas for cooking.....	18
3.2.7. Environmental Protection	18
4. Collection and sorting of the organic waste	18
4.1. The container system.....	19
4.2. Waste collection by vehicles	19
4.3. Waste collection by animal carts	20
5. Building biogas in rural area.....	20
5.1Where to locate a biogas plant.....	20
5.2. Substrates of Anaerobic digestion.....	21

5.3. Process of anaerobic digester and how biogas is produced	22
5.3.1. Hydrolysis	23
5.3.2. Acidogenesis	23
5.3.3. Acetogenesis	23
5.3.4. Methanogenesis.....	23
5.4. Factors affecting the digestion process	23
5.4.1. PH value.....	23
5.4.2. Temperature	23
5.4.3. Loading rate	24
5.4.4. Retention time	24
5.4.5. Toxicity	24
5.5. How does a biogas plant in rural areas?	25
6. Biogas plants	26
6.1Fixed dome plant	26
7. Design of biogas plant in rural Gaza Strip	28
7.1. Result and Calculation the size of digester	29
Table 9: Calculate the appropriate quantities to determine the size of the digester.....	29
7.2. Design biogas plant for the family	30
7.3. Calculating the dimension of the Digester	30
7.4. Cost of building biogas plant	31
8. Investment return of the design and construction of the biogas plant.....	31
8.1. Organic waste and waste water.....	32
8.2. Biogas	32
8.3. Organic fertilizer	32
8.4. The benefit	33
9. Conclusions and Recommendations	33
10. References	34

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List of Tables

Table 1: The elemental concentration of chloride and nitrate in drinking water in the Gaza Strip [WAFA, 2011]

Table 2: The distribution of groundwater reserves by the concentration of chloride in the Gaza Strip [WAFA, 2011]

Table 3: The quantity of nutrients in the one cubic meter of wastewater as follows [WAFA, 2011]

Table 4: The attributes of water flowing from industrial wastewater [WAFA, 2011]

Table 5: Increasing the proportion of sodium chloride and nitrate in water rates by more than the permitted universally in Gaza Strip, [WAFA, 2011]

Table 6: The relation between the temperature and the solubility in water of some gases [Al Seadi T,2008].

Table 7: Toxic level of various inhibitors [BTC, 1989]

Table 8: The material of waste and the amounts

Table 9: Calculate the appropriate quantities to determine the size of the digester

Table 10: Cost of construction materials needed to create the design of biogas plant

List of Figures

Figure 1: Gaza Strip map

Figure 2: Solid waste in the Gaza city.

Figure 3: Drainage pond publishes death traps in Gaza [WAFA, 2011].

Figure 4: Schematic of a biogas plant used for power generation. Source: <https://www.bios-bioenergy.at/en/electricity-from-biomass/biogas.html>

Figure 5: The container system and Waste collection by vehicles [WAFA, 2011]

Figure 6: The benefits of agriculture small-scale biogas plants.

Figure 7: The main process steps of anaerobic digester.

Figure 8: Biogas cycle for Biogas Production.

Figure 9: Indian fixed dome plant Nicarao design [Kishore, V., et al.1998.]

Figure 10: Tanzanian fixed dome plant design [Kishore, V., et al.1998.]

Figure 11: Chinese fixed dome plant design [Kishore, V., et al.1998.]

Figure 12: The design of 12 cubic meters for the digester in biogas plant

1. Introduction

The population of the Gaza Strip is on the rise with nearly 2 million people and the area of the Gaza Strip is 360 square kilometers. The Gaza Strip size is very small relation to the number of population. The Gaza Strip suffers from water pollution from wastewater and organic waste leading to a lot of diseases caused by water pollution. There are only 0.5 to 10 % of groundwater that is suitable for human use according to the World Health Organization (WHO) standards [UNEP, 2009]. A German study showed that there are high levels of nitrate in drinking water in the Gaza Strip which leads to health damage in children [UNEP, 2009]. This is due to the pollution in the groundwater which is the only source of drinking water in the Gaza Strip. In addition a lot of wastewater flows into the Mediterranean Sea which is in dangerous to the environment. About 50 to 80 million liters of untreated sewage or partially treated are discharged into the Mediterranean Sea every day. Therefore, it is necessary to find appropriate solutions to avoid this crisis, as most of the areas in the Gaza Strip (especially rural areas) suffer from a lack of wastewater networks. The rural areas have no supply for sewage disposal, thus every house in the rural area has a big hole next to the house to put the sewage inside the hole. So with the passage of time leads to mixing of wastewater with the groundwater, causing groundwater pollution. This leads to the spread of the diseases between the population, so the rural area needs to manage wastewater and organic waste. Biogas is one of the most important sources of energy today in the Gaza Strip, especially in rural areas. Therefore, the construction of biogas plants in rural areas could help to remove wastewater and organic waste and at the same time could produce biogas. Subsequently, the project is considered one of the most important projects for rural areas that do not have wastewater networks for the disposal of wastewater and organic waste and solve the problem of groundwater pollution, which causes many environmental and health problems, as well as to help people self-sufficiency in the use of biogas for household purposes [UNEP, 2009] [WAFA, 2011].

1.1. Objectives

Objective and purpose of this project is to design a plant biogas plant for the rural areas of the Gaza Strip. The project is carried out by collecting enough information on the amount of organic waste and wastewater produced, as well as the quantity of biogas that could be produced. Additional benefits like production of fertilizers that can be used in agriculture increasing the fertility of the soil is considered.

1.2. Methodology

The project has a literary and technical study that identifies and solves an environment problem and at the same time it was serving the rural area in self-sufficiency of biogas. In this project started the idea to provide something peculiar to the suffering the rural areas of the Gaza Strip. The biogas plant has constructed in the rural areas of the Gaza Strip. The biogas project has emerged in Europe largely, especially in Sweden where it has used as fuel. This project will solve the environmental problems in the Gaza Strip by disposing of organic waste and wastewater that polluted the environment and caused diseases. Biogas self-sufficiency and what was the results of this project? Finally, discuss the important results and how to preserve this project on a permanent basis and which benefit from it.

2. Background

2.1. Location and condition

The Gaza Strip is located in southwest of Palestine with an area of 362 square kilometers. The Gaza Strip is a narrow strip at along of the Mediterranean Sea, 40 km long and from 5 to 15 km wide. The population of the Gaza Strip is more than 2 million Palestinians and the population density is the highest in the world relative to the land size. Where the number of people are about 55 thousand citizens per one square kilometer. As seen in figure 1, the Gaza Strip include five big areas (North Gaza, Gaza, middle area, Khan Younis, Rafah) which are also including the Gaza Strip camps. The results of the statistics by the Central Bureau of Statistics (PCBS) through the year 2006, show that the amount of organic waste produced by the population of the Gaza Strip is estimated at 1116 tons per day, the equivalent of 407, 340 tons per year. These are huge amounts of organic waste which pose a threat to the environment and to the public health [al-Kuwayt, J et al, 2006].



Figure 1: Gaza Strip map.

2.2. Climate of the Gaza Strip

The Gaza Strip is located within a transitional zone between the semi-arid climate of the Sinai Peninsula, the dry desert and the Mediterranean coast. The average of daily temperature ranges between 25 C in the summer and 13 C in the winter and the humidity range is 60% - 80% between day and night. Winds in the Gaza Strip are dominantly northwesterly and vary its speed between night and day. The average annual rainfall is 400 mm. It is known that the climate has a significant impact on the environment where there is a very strong relationship between the spread of environmental pollution and its impact on the air. The mixing of groundwater and surface water with wastewater leads to an increase in the proportion of environmental pollution as well as the spread of diseases. All these environmental harm increase the proportion of environment pollution, spread of diseases and the lack of clean water [al-Kuwayt, J et al, 2006].

2.3. Water pollution in the Gaza Strip

The Gaza Strip suffers from dangerous pollution of the water leading to a significant shortage of groundwater. The percentage of water pollution in the Gaza is up to 97% . Water contains a high percentage of nitrate and chloride, which is one of the causes of kidney failure in the Gaza Strip. The water also contains high rates of some other heavy metals such as lead and also high levels of sulfur that can affect people's health. Untreated wastewater is one of the most important sources of water pollution in the Gaza Strip because it flows through open channels through populated areas and agricultural areas. The control and treatment of wastewater in the Gaza Strip is important for environmental safety [al-Kuwayt, J et al, 2006] [WAFA, 2011].

The emergence of the pollution problem of the water in the Gaza Strip area is significant, as a percentage of chloride in some areas are up to 1500 mg / liter. The areas from which the water is extracted should have chloride levels less than 250 mg / liter. From Tabel 1 we can see that useable water range between 4-95%. The Northern area and Rafah in the south have the best water quality but they are limited areas that do not exceed 45 square kilometers in the northern regions, and 35 square kilometers in the southern region. The water in the Gaza Strip is alkaline, for example, wells located in the Rafah, Khan Yunis and al-Bureij areas, and Gaza City is located within the alkaline earth water area. Twentyfive % of the water wells in the Gaza Strip are destroyed, the salt ratio has reached more than 1,000 mg / l in the southeastern region and parts of the central region. Since the increasing of the pollution in the water leads to the spread of many diseases throughout the population, there is also economic problem to the society.

As shown in Table 1 and 2, the percentage of chloride in the Gaza Strip increased significantly, so the generally ranging is between 500-1000 mg / l. The nitrate level in the groundwater has also increased, where most water has levels above 50 mg nitrate per liter. These levels have been increasing in areas with high population density and in agricultural areas. This is due to the increasing of wastewater in the Gaza Strip, the lack of a complete wastewater network, and the excessive use of pesticides and fertilizers [WAFA, 2011].

Table 1: The elemental concentration of chloride and nitrate in drinking water in the Gaza Strip (WAFA, 2011)

Area	Nitrate less than 50 mg / l	Chloride less than 250 mg / l
Northern area	10%	95%
Gaza City	6%	23%
Middle area	10%	4%
Khan Yunis	5%	6%
Rafah	5%	90%

Table 2: The distribution of groundwater reserves by the concentration of chloride in the Gaza Strip (WAFA, 2011)

Inventory million cubic liters	Element concentration of chloride mg / l
800	Less than 250
1500	250-500
27000	500-1000

2.4. Environmental pollution in the Gaza strip

Organic waste and wastewater are the biggest environmental problems in the Gaza Strip. Organic waste is one of the most important components of the solid waste in the Gaza Strip which accounts for 98% of total solid waste. The percentage of organic waste varies according to geographical distribution in Gaza strip. Wastewater is a major problem in the Gaza Strip that affects the lives of the citizens of the Gaza Strip permanently. Wastewater causes many health and environmental problems harmful. Wastewater is a source of unpleasant odors that often damage the human respiratory system, cause many diseases and epidemics, and contaminate soil and groundwater [WAFA, 2011] [al-Kuwayt, et al., 2006].

2.4.1 Solid waste



Figure 2: Solid waste in the Gaza city Source :

<https://www.bioenergyconsult.com/waste-management-in-gaza/>

The solid waste in the Gaza Strip is one of the most prominent and important issues. This problem increases in the Gaza Strip with the population increases, the amount of consumption increases, and the amount of waste increases. The amount of solid waste per capita is between 650-1200 mg [WAFA, 2011].

As shown in Figure 2, these wastes are disposed of in landfills that are not environmentally friendly, and contrary to environmental health requirements. The waste is disposed of by incompletely burned, so the hidden layers of waste remain a breeding ground for insects and rodents. The Ministry of Planning estimated the amount of waste generated by Gaza is 1300 tons / day [WAFA, 2011].

The organic waste is considered the most important component of solid waste in the general in the Gaza Strip. The organic waste amounts to 98% of the total solid waste, the percentage varies according to the geographical distribution in the Gaza City. It is known that the organic waste decomposes rapidly, as it results in emissions of gases, fumes and odors, and the spread of harmful insects that fly and crawl. Also, the spread of toxic gases as a result of burning waste has a direct impact on public health [WAFA, 2011].

2.4.2 Wastewater



Figure 3: Drainage pond publishes death traps in Gaza [WAFA, 2011].

The wastewater in the Gaza Strip is a major problem affecting the environment and the population. The wastewater networks in the Gaza Strip cover 60% of homes and buildings, while 40% depend on cesspits that leak into the groundwater. Wastewater is discarded into the sea, 80% of the wastewater goes to the sea and 20% seeps into the groundwater. This amount is estimated at 30 million cubic meters per year [WAFA, 2011].

As shown in Table 3, the percentage of nitrogen, phosphorous and potassium is shown in one cubic meter of wastewater. The amounts of these components are in untreated wastewater and wastewater in ponds. This percentage is considered high in one cubic meter, where the level of those substances in wastewater poses a threat to the environment and drinking water; this leads to wastewater seepage into the groundwater, which increases the risk [WAFA, 2011].

Table 4 shows the amount of some substances flowing from industrial areas into wastewater, showing high levels of COD, TDS, Al, and TSS. This poses a real threat to drinking water, groundwater and the environment. The high percentage of these substances in the water causes also chronic and deadly diseases [WAFA, 2011].

As shown in Table 5, there is an increase in the amount of salts, especially nitrates in water (drinking water). So this amount is greater than the internationally permissible average, therefore a high proportion of nitrates in drinking water causes a risk to humans and the environment. The main reason for this problem is that the mixing of wastewater with groundwater. The high amount of nitrates in water may create cancer tissues in the human body, especially children [WAFA, 2011].

Table 3: The quantity of nutrients in the one cubic meter of wastewater as follows [WAFA, 2011]

Element	Untreated wastewater	Wastewater from the ponds
Nitrogen	20-100 g	30-60 g
Phosphorus	6-20 g	8-18 g
Potassium	10-50 g	14-45 g

Table 4: The attributes of water flowing from industrial wastewater [WAFA, 2011]

Industry	Parameter							
	COD mg/1	TDS mg/1	TSS mg/1	pH mg/1	Al U/1	RE mg/1	Cu mg/1	Zn mg/1
Textile Dyeing	1042	4586	375	7.5	NM	0.27	0.05	0.62
Jeans Washing	2290	1180	6711	7.4	NM	0.4	BDL	0.55
Car Washing	700	1510	1142	7.7	NN	0.50	0.11	0.08
Photo Processing	4250	31300	86	9.5	234	1160	0.08	1.82
Electroplating	630	2400	86	9.5	220	0.60	9.20	20.8
PSI*** Standard	150	3000	6.5-9	5	1	2	2	Not yet

Table 5: Some parameters in drinking water compared to WHO guidelines in Gaza Strip, [WAFA, 2011]

Parameter	WHO	Beit Hanoon	Beit Lahya	Jabalia	Gaza	Middle Area	Khnyounis	Rafah
EC (ms/cm)	1.2	1.6	0.8	1.2	2.5	3.5	5.0	3.5
TDS (mg/l)	1000	1000	420	800	1800	2800	3200	1900
CT (mg/l)	250	400	60	130	650	1400	1200	1300
F (mg/l)	1.5	1.4	0.5	0.7	1.0	1.6	2.8	2.8
NO ₃ ⁻ (mg/l)	45	40	115	70	90	130	100	120
SO ₄ ⁻ (mg/l)	250	35	45	40	200	250	700	200
Na ⁺ (mg/l)	200	180	40	75	650	700	650	600
Hardness (CaCO ₃ mg/l)	500	200	300	350	430	650	600	550
Ca ²⁺ (mg/l)	100	65	70	80	80	75	100	110
Mg ⁺ (mg/l)	60	45	40	45	50	55	75	90

3. Why biogas

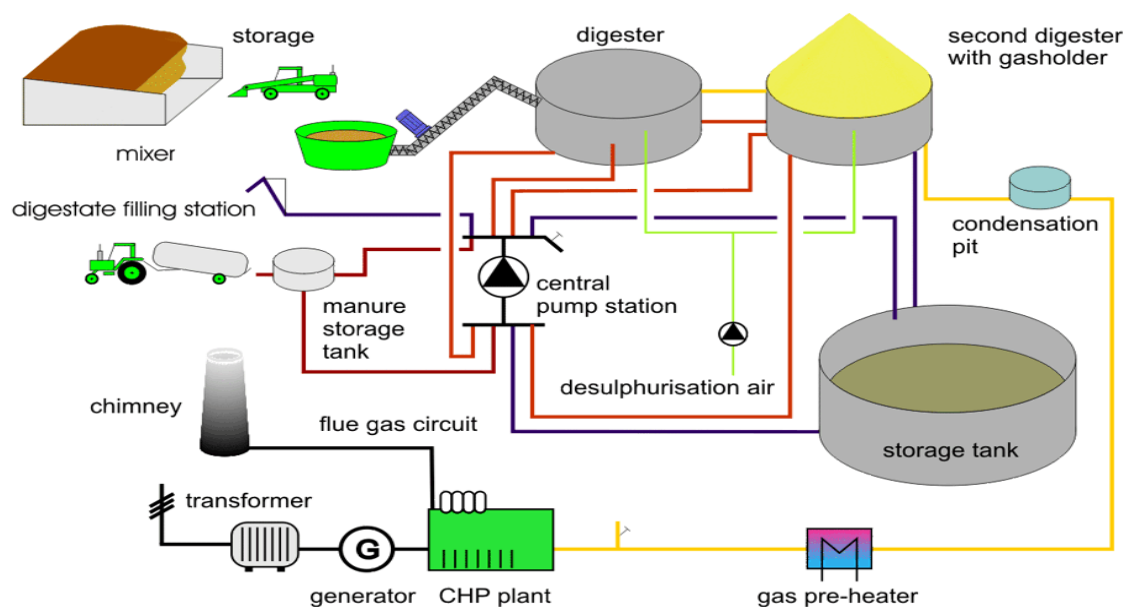


Figure 4: Schematic of a biogas plant used for power generation. Source: <https://www.bios-energy.at/en/electricity-from-biomass/biogas.html>

3.1. Biogas composition

Biogas is one of the most important sorts of energy, as it is mainly produced from organic waste, animal waste, vegetation, wastewater, landfills etc. Biogas consists of a mixture of gases which is mainly composed by methane (CH_4) (50-75%) and carbon dioxide (CO_2) (25-50%); however, minor quantities of gases as hydrogen sulfide, ammonia, nitrogen and hydrogen are present which usually less than 1% of the total gas volume [Hassan, 2004].

3.2. The benefits of biogas

3.2.1. Disposal of organic waste and wastewater

Organic waste and wastewater cause a great danger to humans, the environment and living organisms which are among the most environmental problems in the Gaza Strip. Thus it must be organized and disposed of in a safer way to the environment. Therefore it is important to build a biogas plant in rural areas to get rid of all organic waste and wastewater [Alseadi et al. 2008].

3.2.2. Provides renewable energy

It is well known that renewable energy is important nowadays. The biogas provides renewable energy that does not give harm to the environment. It also helps the people to use it in various areas of life. Therefore the biogas is one of the important sources of renewable energy which is also sustainable and permanently [Alseadi et al.2008].

3.2.3. Production of organic fertilizer

The biogas plant helps in the production of organic fertilizers which is a good nutrient for the growth of plants since it contains phosphorous, nitrogen and potassium which helps in the growth of plants [Alseadi et al. 2008].

3.2.4. Improve sanitation

The biogas plant accommodates a big amount of organic waste and wastewater which leads to improved sanitation and avoid environment pollution and diseases that come from those. Therefore, the a biogas plant can disposal of wastewater and organic wastes which is good to improve sanitation [Alseadi et al. 2008].

3.2.5. Create jobs in rural areas

The biogas plant needs daily work which leads to creating job opportunities for citizens, especially in rural areas. So the biogas plant creates job opportunities for citizens and helps them to dealing better with the life [Alseadi et al.2008].

3.2.6. The production of biogas for cooking

The biogas plant helps produce cooking gas which helps in achieving self-sufficiency in cooking gas. The Gaza Strip suffers from a serious shortage of natural gas which is used for cooking. Consequently, the biogas is a good alternative for cooking gas [Alseadi et al.2008].

3.2.7. Environmental Protection

Although containing methane, which is a greenhouse gas, if contained properly, the gas will not harm the environment. Thus, it is easy to use biogas permanently. The biogas plant is important for the disposal of organic waste and wastewater which is one of the most dangerous threats to the environment. The Gaza Strip suffers extremely from pollution of organic waste and wastewater. Through the biogas plant, a non-polluting environment is preserved which gives a beautiful picture of the environment [Alseadi et al.2008].

4. Collection and sorting of the organic waste

Organic waste in the Gaza Strip is transported to random places contrary to environmental health regulations. It is incompletely burned, as the bottom layers of the waste remain and becomes a haven for insects, rodents and a source of bad odors. The organic waste situation in the Gaza Strip is not comparable to the situation in other places. There is a large amount of organic waste in the Gaza Strip due to its high population density. It is important to have good solid and organic waste management that is considered safe for the citizen and the environment which protects the citizen from the damages resulting from the disposal or recycling of waste. It is a big thing that one did in supporting the national economy and in giving a beautiful civilized image of society [Omar, 2013][Abdalqader el al., 2012]. The Gaza Strip depends on several methods for collecting solid and organic waste. The collection container system is one of the general methods for organic waste in order to facilitate process. Containers are collected by vehicles to be transported to landfills. Then it is transferred to the main landfill by large amount of organic waste (70%) which in turn is used in biogas plants. In this project it is possible to get rid of organic waste and wastewater by the biogas plant which needs large amount of organic waste and waste water. It gives self-sufficiency in biogas and waste disposal, so it has a great benefit in rural areas [al-Kuwayt, et al. 2006] [Omar, 2013] [Abdalqader, et al.2012].



Figure 5: The container system and Waste collection by vehicles [WAFA, 2011].

4.1. The container system

As shown in Figure 5, The Gaza Strip depends on containers system on the streets and in front of homes to facilitate the easy disposal of solid waste by people. Where this method of collecting solid waste in the Gaza Strip has not proven effective and efficient, not because of the low number of containers, or the lack of direct capacity, or the distance from the places of the population, but for several reasons areas [al-Kuwayt, el al. 2006] [Omar, 2013] [Abdalqader, el al.2012].

1. The low level of environmental awareness among people, which is transporting waste from his home to the container and shedding the waste close to the container instead of placing it inside the container.
2. Children often use to do the transport solid waste from home to the container, which makes these children throw them next to the container.
3. There is no strong law and ecosystem for people to throw solid waste into the container and are forced to pay a fine if they do not do so.
4. Add to this the limited number of containers.

4.2. Waste collection by vehicles

As shown in Figure 5, it is a useful method of solid waste collection and it is done by car (tractor) whose crew consists of one worker or a number of workers in addition to the driver. They pass through streets in front of the homes and collect garbage. Then, they put them in the cart, and thereafter the cart is emptied into the landfill areas [al-Kuwayt, el al. 2006] [Omar, 2013] [Abdalqader, el al.2012].

4.3. Waste collection by animal carts

This method is still used in some remote areas, or areas that can not be reached by vehicles. Where some people transport solid waste from front of the house to the landfill in exchange for payment of transportation costs by a home owner areas [al-Kuwayt, el al. 2006] [Omar, 2013] [Abdalqader el al.2012].

In the Gaza Strip according to population density, this produces large quantities of solid waste, which must be properly managed in the Gaza Strip. Especially in rural areas. So in this project organic waste and wastewater can be disposed of by a biogas plant, which final disposal of organic waste and water Sanitation, which is of great benefit in rural areas.

5. Building biogas in rural area

The building of biogas station is important in rural areas which gives citizens the full utilization. The biogas is used in cooking and also helps in the lighting and power generation. The building of biogas station helps rural areas in agriculture by using fertilizers which produced from biogas plant. It is also important project that provides jobs opportunities for citizens in rural areas [Al Seadi et al., 2008].

5.1. Where to locate a biogas plant

There should be a suitable site for setting up a biogas plant which means that the distance between the residents and the biogas plant should be appropriate. The list below describes some important considerations before selecting a biogas plant site [Al Seadi et al., 2008].

1. The location of the biogas station should be at an appropriate distance from the residential areas to avoid any inconvenience to them.
2. The direction of the wind must be observed in order to avoid the arrival of odors generated by the wind to the residential areas.
3. The site should have easy access to infrastructure such as the electricity grid.
4. The soil site must be inspected before construction begins.
5. The site chosen should not be in an area affected by floods.
6. The site size should be appropriate for the activities carried out and the amount of biomass supplied.

5.2. Substrates of anaerobic digestion

The anaerobic digestion is a closed region in which a biochemical process occurs where organic waste and waste water are decomposed by bacteria from anaerobic microorganisms in the absence of oxygen. The anaerobic digestion process is common in many natural environments that produce the biogas. The biogas and fertilizer are produced through the process of digestion and the methane is the main gas in the formation of biogas. There is a wide range of types of biomass can be used as substrates for the production of biogas from the anaerobic digester such as animal manure and slurry, agricultural residues, organic wastes digestible organic wastes from agro industries, waste water, sewage sludge and dedicated energy crops [Pabón Pereira et al., 2013] [Al Seadi, et al., 2008].

As shown in Figure 6, there is a wide range of biomass types that can be used as substrates for biogas production from anaerobic digestion. The most common biomass classes are listed below.

- Animal manure and slurry
- Agricultural residues and by-products
- Digestible organic wastes from agro industries (vegetable and animal origin)
- Organic fraction of municipal waste and from catering
- Sewage sludge
- Dedicated energy crops (e.g. maize, miscanthus, sorghum, clover)

These substrates are relied upon in the biogas production process which is made by the absence of oxygen and the reaction of the anaerobic bacteria present in digester [Pabón Pereira et al., 2013] [Al Seadi, et al., 2008].

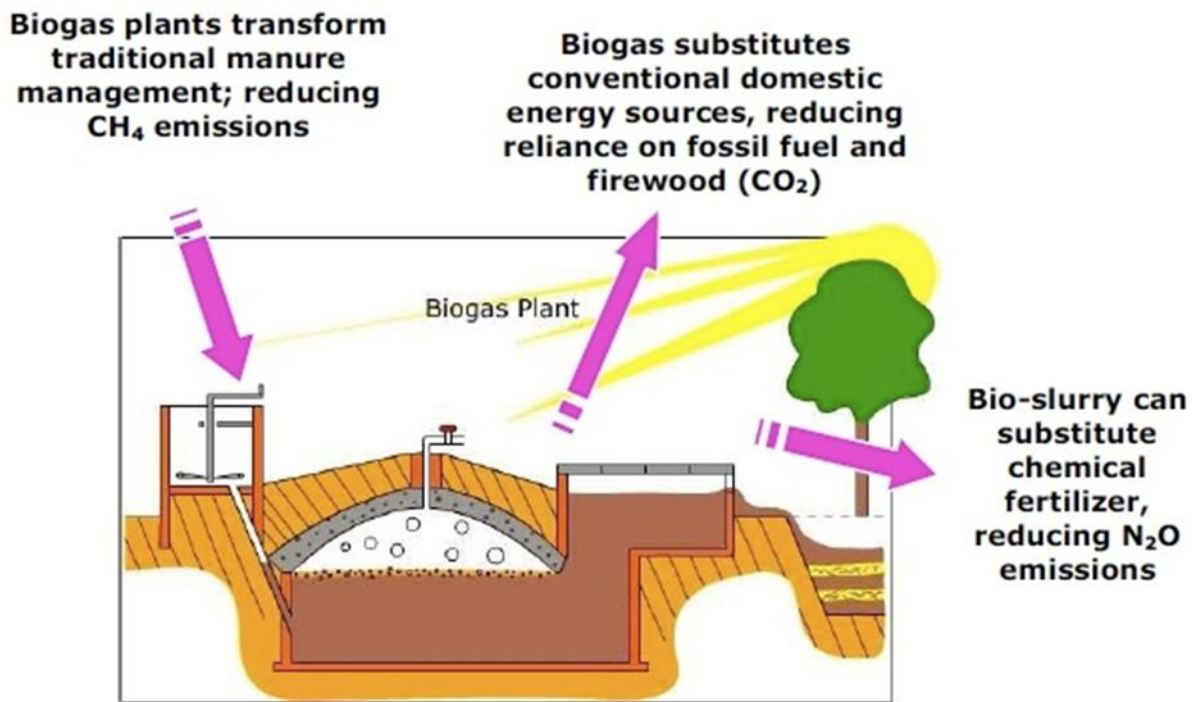


Figure 6: The benefits of agriculture small-scale biogas plants source : bild a biogas plant
[<https://www.build-a-biogas-plant.com/>]

5.3. Process of anaerobic digester and how biogas is produced

The process of digestion occurs to substances by presence of the bacteria in the absence of oxygen so-called digestion anaerobic. As shown in the figure7, the process composition of biogas formed through four main steps hydrolysis, acidogenesis, acetogenesis, and methanogenesis [Al Seadi, et al., 2008].

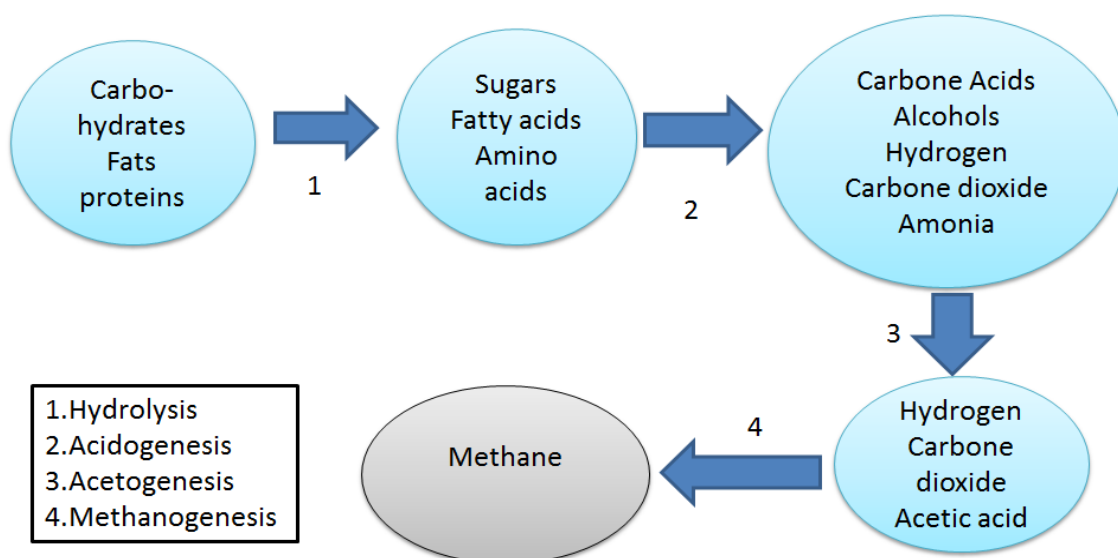


Figure 7: The main process steps of anaerobic digester

5.3.1. Hydrolysis

The stage of decomposition (hydrolysis) is a biodegradable material which contains organic materials such as carbohydrates, proteins, fats is broken down by help of an enzyme of bacteria in the absence of oxygen. Through this process it is converted into organic materials such as sugars, fatty acids and amino acids.

5.3.2. Acidogenesis

The stag of acidogenesis is the stage of converting the compounds resulting from the hydrolysis by such as simple sugars, fatty acids and amino acids into more simple compounds such as acetate, alcohol, hydrogen, carbon dioxide and ammonia.

5.3.3. Acetogenesis

This stage of acetogenesis is the final stage to converting the compounds with long chains carbon to short chains carbon as shown in fig 7.

5.3.4. Methanogenesis

The final stage is that the formation of methane which has 70% of the biogas and 30% of residual gas such as carbon dioxide and hydrogen. Through this process, the acetic acid is converting to methane in the presence of activity bacterial to complete formation of methane which is the most important part in the production of biogas.

5.4. Factors affecting the digestion process

5.4.1. pH value

pH has an effect on the process of producing biogas. The pH in the digester should be moderate between 7-8 and the pH is optimized for formation of biogas [Pabón Pereira et al., 2013] [Al Seadi, et al., 2008].

5.4.2. Temperature

As shown in table 6, the temperature is one of the factors affecting the stages of formation of biogas. The low temperatures (8-10 ° C) and high temperature (>40 ° C) give less biogas production so the best level of temperature is from (25-35 ° C) [Pabón Pereira et al., 2013] [Al Seadi, et al., 2008].

Table 6: The relation between the temperature and the solubility in water of some gases [Al Seadi T,2008].

Gas	Temperature (°C)	Solubility mmol/l water	Changed solubility 50°C-35°C
Hydrogen	35	0,749	3,3 %
	50	0,725	
Carbone dioxide	35	26,6	36 %
	50	19,6	
Hydrogen sulphide	35	82,2	31 %
	50	62,8	
Methane	35	1,14	19 %
	50	0,962	

5.4.3. Loading rate

The loading rate depends on the size of the digester, the amount of organic materials and the quality of the substrate. The digester should have the large capacity so that it contains a large amount of organic material to increasing the rate of production of biogas.

5.4.4. Retention time

Retention time is the time required to keep the organic material in the digester until the reaction is complete. Then, it should know the time required as well as the amount needed for the size of the digester and the amount of additive daily. The retention time depends also on the temperature which is approximately 35 ° C to producing the required amount of biogas.

5.4.5. Toxicity

The toxic compounds have a significant effect on the production of biogas such as heavy metals (zinc, chromium, copper, lead and other), metal ions (sodium, potassium, magnesium, ammonium and other), detergents and soap. The toxic compounds in the digester have a role in inhibit the growth and activity of bacteria which decrease the production of biogas.

As shown in tables 7, there are some inhibitors in the digester and determine the level of toxicity of the various inhibitors.

Table 7: Toxic level of various inhibitors [BTC, 1989].

S. N.	Inhibitors	Inhibiting Concentration
1.	Sulphate (SO_4) ⁻²	5.000 ppm
2.	Sodium Chloride or Common salt (NaCl)	40.00 ppm
3.	Nitrate (Calculated as N)	0.05mg/mL
4.	Copper (Cu^{+2})	100 mg/L
5.	Chromium (Cr^{+3})	200 mg/L
6.	Nickel (Ni^{+3})	200 - 500 mg/L
7.	Sodium (Na^{+})	3.500 – 5.500 mg/L
8.	Potassium (K^{+})	2.500 – 4.500 mg/L
9.	Calcium (Ca^{+2})	2.500 - 4.500 mg/L
10.	Magnesium (Mg^{+2})	1.00 – 1.500 mg/L
11.	Manganese (Mn^{+2})	Above 1.500 mg/L

5.5. How does a biogas plant in rural areas work

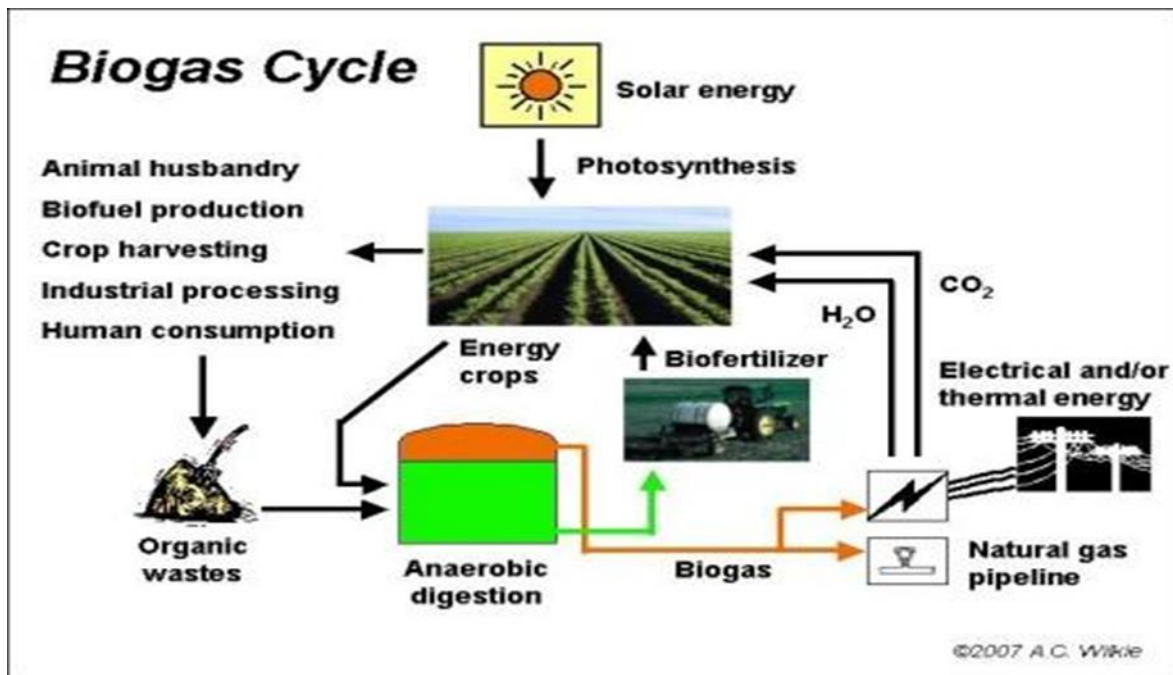


Figure 8: Biogas cycle for Biogas Production. Source: <https://biogas.ifas.ufl.edu/digesters.asp>

As shown in the figure 8, the operation of the biogas plant in rural areas depends on the main components to complete the production of biogas, the sediments of collecting organic tank, tank digester, tank assembly mud and fertilizers, tank assembly biogas. These components of the biogas plant are necessary to complete the biogas plant. Each stage is depended on how to build the station to be permanently, by completing each stage.

The stage of collecting organic waste, sewage, animal manure, and plant waste are combined in the deposits of organic tanks that contain fats, sugars, acids and others to produce biogas.

The stage of tank digester, the components is transferred to the tank digester for the production of biogas. As shown in figure 7, the process of anaerobic digester and how biogas is produced has been explained in detail above. It can see that the digester stage of the most important stages which are considered actual for the production of biogas.

The stage of the tank assembly mud and fertilizers (output) after the digestion process is important after the completion of digester stage and produce biogas. Where the output is mud and fertilizer which is used in agriculture in the form of fertilizer agricultural, which is the stage of production of fertilizers.

The final stage is the stage tank assembly biogas. After all these stages are grouped biogas, which is considered one of the most important result of biogas plant. The biogas is used in cooking, through the production of biogas is self-sufficient to meet the needs of the people which is used also in the home lighting in rural areas. The biogas plant is one of the most important projects in the self-sufficiency of biogas.

6. Biogas plants

There are many types of digester plants such as fixed-dome plants, floating-drum plants, Balloon plants, Horizontal plants, earth-pit plants, Ferrocement plants and other. This thesis includes the establishment of a biogas plant with one of the types of digester plants for being being built in rural areas. Through this project, the rural areas can directly eliminate wastewater, organic waste and self-sufficient in producing biogas [Kishore, et al.,1998].

6.1. Fixed dome plant

The fixed dome plant is a type of plants often found in rural areas. This station was designed by Indians and Chinese which has proven its sustainability over the years as a natural cost for rural areas. The station is built underground due to space saving and also protection from damage which works also in summer and winter. This makes the sustainability of this plant up to 20 years or more.

There are several types of fixed-dome plants as shown in Figure 9, 10, and 11. Where the design of figure 9 is an Indian design , the design of figure 10 is a Tanzanian design, and the design of figure 11 is a Chinese design and due to demand growing on this type of plants,which were selected for biogas plant. So the minimum size of this plant is up to 5 cubic meters, and this type of plant is expanded as needed for up to 200 cubic meters.

The basic components of the fixed dome plant (Nicarao design) are shown in the figure 9. Figure 9 shows all parts of the plant, 1. Mixing tank with inlet pipe and sand trap, 2. Digester, 3. Compensation and removal tank, 4. Gasholder, 5. Gaspipe, 6. Entry hatch, with gastight seal, 7. Accumulation of thick sludge, 8. Outlet pipe, 9. Reference level, 10. Supernatant scum, broken up by varying level [Kishore, et al.,1998].

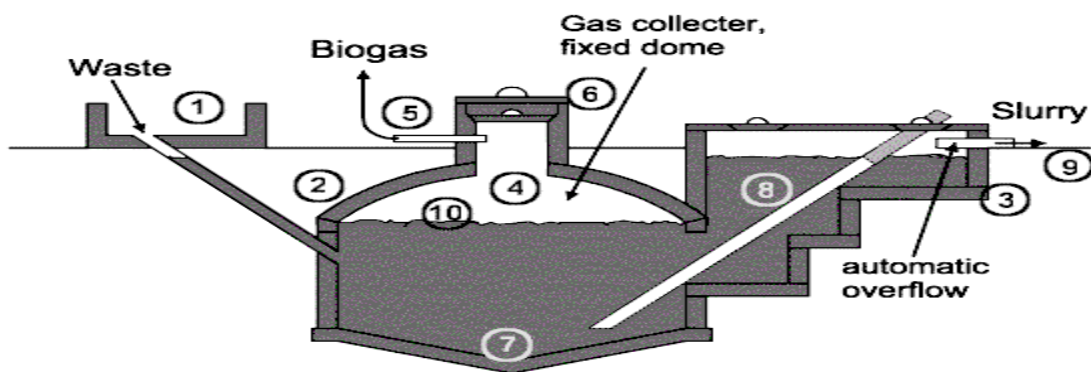


Figure 9: Indian fixed dome plant Nicarao design [Kishore, et al.1998.].

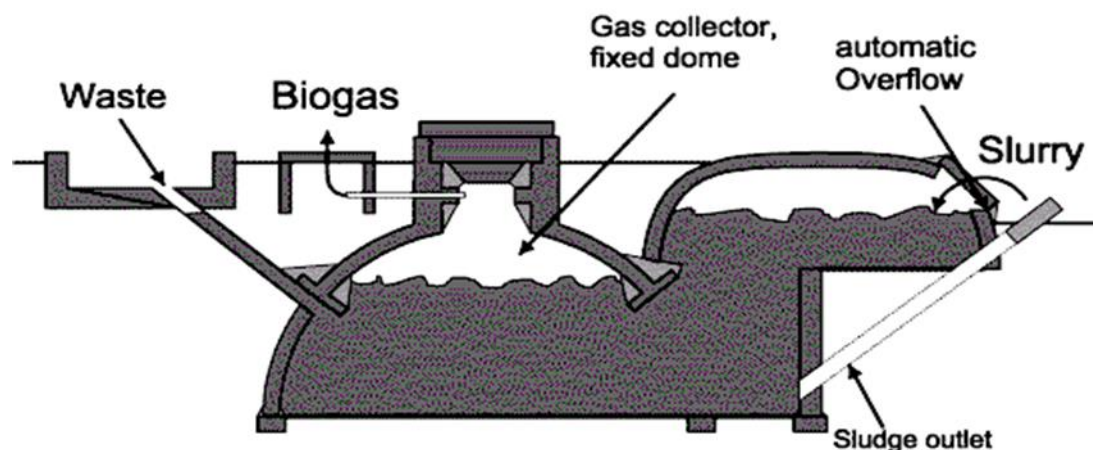


Figure 10: Tanzanian fixed dome plant design [Kishore, et al.1998.].

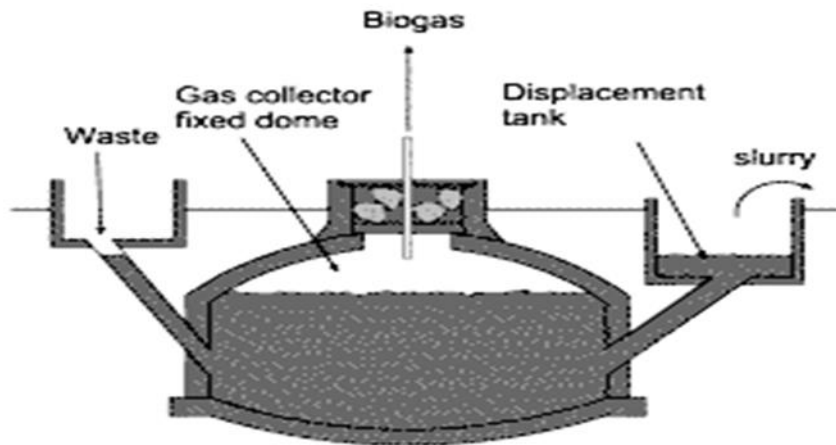


Figure 11: Chinese fixed dome plant design [Kishore, et al.1998.].

The rural areas in the Gaza Strip suffer from lack of access to electricity, sanitation and waste disposal which makes these areas more vulnerable to pollution. Moreover it also depends on itself (self-sufficiency) in biogas production which is used also in cooking. This type of plant as shown in Figure 3 is good to use to meet the needs of citizens and to dispose of solid waste and sanitation.

7. Design of biogas plant in rural Gaza Strip

The biogas plant in rural areas is designed to suit those areas in terms of living conditions and rural life. Therefore, the design of work in rural areas must be commensurate with the local population as well as in terms of the cost of the factory that is appropriate for the local population.

As shown in the table 8, the rural areas in the Gaza Strip depend directly on natural gas. Since the natural gas in the Gaza Strip is expensive and sometimes missing so the Fixed dome plant Nicarao design provides biogas for electricity and cooking and also permanently. In the Gaza Strip, 24 kg of natural gas is approximately used per month which is equivalent to 48 kg of biogas. About 600 to 1200 g of organic waste is produced per person per day. One cow produces about 12 kg of dung. According to the increase in population in the Gaza Strip, the family equals four manure of cows ($4 * 12 = 48$ kg) for a house. According to some studies [Medyan Hassan, 2004] [Nazir, 1991] [Al Seadi, et al., 1998], the one kg of manure and waste produce 51.9 grams of biogas. The manure and waste is reduced by 1 to 3 percent of the water, and this is also an excellent ratio for biogas production. In this design, there will be retention time that equates to 50 days. The retention time was chosen for 50 days based on

previous studies, and it is also considered an appropriate time to produce a sufficient amount of biogas. The organic waste and wastewater will be diluted by one to three units of water. So this design is based on the mentioned data.

Table 8: The material of waste and the amounts.

Material of waste	Amount
Organic household waste	About 600 to 1200 g per person per day
The dung of one cow	12 kg per day
Organic waste and wastewater (the dung of four cows)	48 kg per day
The Kg of manure and waste	51.9 % of biogas
Organic waste and wastewater for a family	25 kg of biogas

7.1. Calculation the size of digester

Table 9: Calculate the appropriate quantities to determine the size of the digester.

	Calculate the appropriate quantities to determine the size of the digester
Dung ratio (waste) to water	3: 1 (dilution)
The size of Holder gas	Half the size of digester gas
Retention time	50 days
The amount of animal manure unit (organic waste) resulting from the Family day	$12 \times 4 = 48$ liters (L)
The amount of water used to dilute (organic waste)	$48 \times 3 = 144$ L
The volume of waste with water consumer per day	$48 + 144 = 192$ L
Total size of the digester without gas holder = the volume of waste with water used daily \times retention time	$192 * 50 = 9600$ L = 9.6 m^3
The volume of gas holder	$0.5 \times 9.6 = 1.9 \text{ m}^3$
The final size of the digester	$1.9 + 9.6 = 11.5 \text{ m}^3 = 12 \text{ m}^3$

In Table 9, the volume of digester to be designed in the biogas plant is calculated so these results are based on its previous studies. The design will be specific to this thesis and this design is for one family. The size of the digester equals 12 cubic meters which can serve the one family for 50 days. Subsequently, the rural family has self-sufficient of biogas in daily life.

7.2. Design biogas plant for the family

The biogas plant was designed to suit the rural family in the Gaza Strip. In this design the best option was the fixed dome plant which is shown in Figure 9. It runs for 50 day as a retention time and low cost which is easy to repair and restore over time. Therefore, the efficiency and selectivity are good. So it is easy for the citizen rural disposal of organic waste and wastewater and self-sufficiency of bio-gas for cooking and to generate the electricity needed for the family. It is necessary to build a biogas plant in rural areas, and this is what will be explained in this design as shown in figure 12.

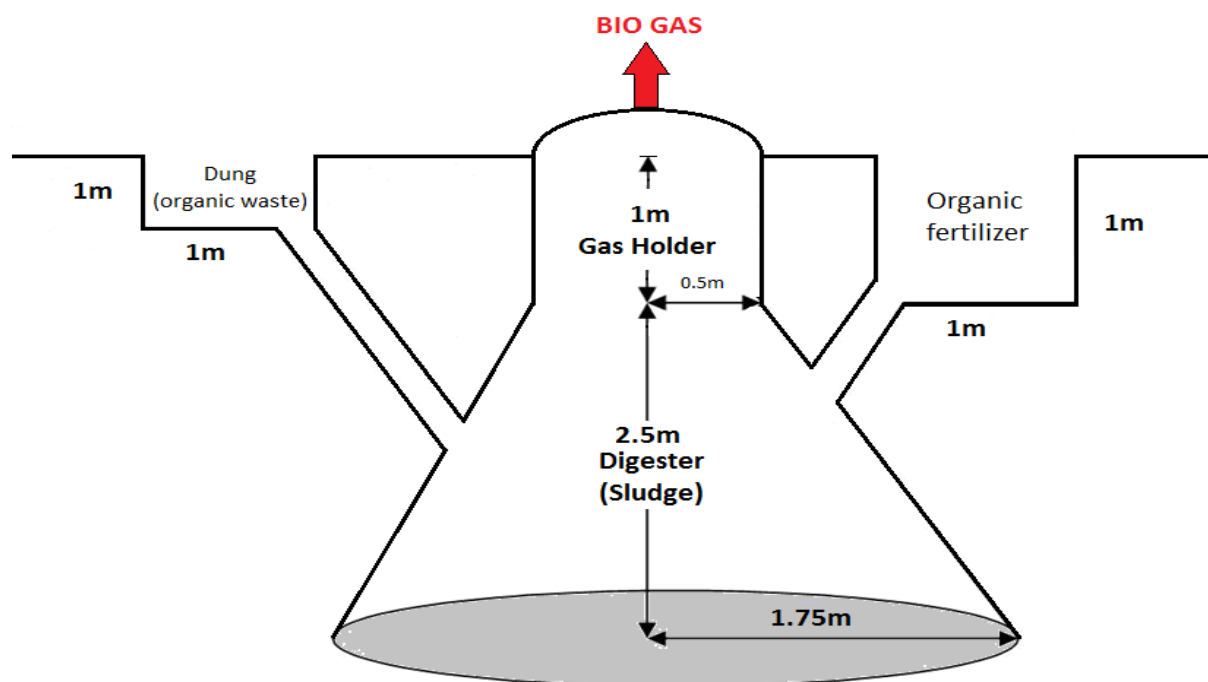


Figure 12: The design of 12 cubic meters for the digester in biogas plant.

7.3. Calculating the dimension of the Digester

At the first, it is necessary to know the volume of the digester which is equal to 12 cubic meters. As we see in Figure 4, some information is constant and known such as depth, upper width, upper cylinder depth but bottom width is variable. For calculating the bottom width, I

used Microsoft excel to calculate it. by using the equations below, the radius of 1.75 meters was obtained and thus the full size of the biogas plant was obtained.

The equations that are used are:

The volume of Digester: $V_1 = \frac{\pi}{3} \times h_1 \times (r_1^2 + r_2^2 + r_1 r_2)$

The volume of Gas Holder: $V_2 = h_2 \times (\pi \times r_2^2)$

V_1, V_2 : Cubic meter. h_1, h_2 : Meter. r_1, r_2 : Meter. π : Pi

7.4. Cost of building biogas plant

The cost of building a biogas plant requires equipment and labor. After inquiring from a number of men with experience in the construction field about the cost of building a biogas plant and the cost of the necessary equipment. The costs can be estimated in the following transformation as shown in Table 10.

Table 10: Cost of construction materials needed to create the design of biogas plant

Requirements	Cost (\$)
Digging operation with workers	300 \$
Stones (540 stone, 40cm*20cm*20cm)	300\$
Sand (0.5 ton)	10\$
Cement (17 bags, each bag 50 kg)	100\$
Plastic pipes	20\$
Miscellaneous (gas valve, bricks, plastic, wood, others)	200\$
Total	930\$

After clarifying the prices for setting up a biogas plant through Table 2, it turns out that the biogas plant for the rural family has an acceptable cost of \$ 930.

8. Investment return of the design and construction of the biogas plant

In this project, the focus was on biogas production (self-sufficiency). By designing the biogas plant, organic waste and wastewater are disposed of and it helps in the production of

agricultural fertilizers. Thereafter, it is possible to know the amount of biogas production, the cost of biogas, the amount of fertilizer, the cost of fertilizers and the amount of disposal of organic waste and wastewater.

8.1. Organic waste and waste water

One of the aims of this project is to get rid of organic waste and wastewater in the rural areas of the Gaza Strip. Through this project, organic waste, wastewater and animal dung can be disposed of approximately four cows which mean approximately 48 kg per family. So it helps the rural family to dispose of wastewater and organic waste. It suppose that the village with 50 homes and each home contains a biogas plant, we find that we get rid per day almost = $50 \times 48 = 2400$ kg per day so the biogas plant in this project to accommodate all this amount.

8.2. Biogas

The biogas in rural areas is important to many needs such as cooking, lighting, and electricity. What we seek in this project is self-sufficiency in the production of biogas, which is the case in the one tube of natural gas in the Gaza Strip at a cost of 10 dollars. According to the study conducted in Palestine, West Bank (Medyan Hassan, 2004), it was found that all the kg of manure and waste give 51.9% of biogas. 48 kg of manure, organic waste and wastewater per day produce about 25 kg of biogas which means about 600 kg of biogas per a month, and this saves \$ 20 of natural gas for the rural family in the Gaza Strip. The family uses two tubes of natural gas per day which equals \$ 20 through the design of the biogas plant will save \$100 a month per family which makes the local people self-sufficient of biogas.

The biogas production for 4 cows = $48 \times 51.9\% = 25$ kg/day

The biogas production per month = $25 \times 30 = 750$ kg /month

Cost of produced biogas per month = $750 \times 0.5 \text{ NIS} = 375 \text{ NIC /month} = 100 \text{ \$/month}$

The biogas production per 50 days = $25 \times 50 = 1250$ kg /50 days

Cost of produced biogas per 50 days = $1250 \times 0.5 \text{ NIS} = 625 \text{ NIC /50days} = 170 \text{ \$/50days}$

8.3. Organic fertilizer

The sediments from the biogas plant can be used as fertilizers in agriculture. Therefore, it helps in agricultural production. The price of a ton of the fertilizer is about \$ 75. The organic waste and wastewater for the family produces about 48 kg per day after the production of biogas. The amount of organic fertilizer per month is about $48 \times 30 = 1440$ liters per month which equivalent to 1.5 tons per month so the cost of agricultural fertilizer is $1.5 \times 75 = \$ 113$ per month. This shows that the rural

family provides \$ 113 per month which also increases self-sufficiency of agricultural growth and also to get rid of organic waste and wastewater.

As mentioned in the previous chapters the price of 1 ton fertilizer 200 NIS/ton about almost 75\$/ton.

Volume of daily fertilizer produced=volume of daily waste fed = 48 kg /day

Monthly fertilizer produced = 48 x 30= 1440 kg/month = 1.5 ton/month

Fertilizer cost= 1.5 x 75 = 113 \$/month.

8.4. The benefit

The benefit of these investments lies in the self-sufficiency of biogas in rural areas. Fertilizer production that help in agricultural growth and disposal of organic waste, wastewater and other. The cost is as follows.

Interest resulting from the biogas plant = biogas produced + fertilizer produced-monthly costs

$$=100\$/month +113\$/month - 20\$/month=193 \$/month$$

$$=193*12=2316 \$/year$$

The time required to return the cost of the biogas plant =capital / yearly investment

$$= 930/2316 = 0.4year = 5month$$

Through these results, the construction of the biogas plant in rural areas is not expensive whereas show that the rural family back the cost of building the biogas plant after less than half a year and it is a good time too. So the results and calculations are clear that the rural family is self-sufficient of biogas, the dispose of organic waste and wastewater and agricultural growth by the fertilizers from the biogas plant.

9. Conclusions and recommendations

The design of biogas plant in this research depends on the amount of organic waste and wastewater resulting from the family in the rural area. A biogas plant was designed to solve those problems based on the fixed dome plant design as shown in Figure 3 and 4. So after making calculations it shows that the volume of the used digester which is equal to 12 cubic meters as shown in Figure 4. Where the construction is cost of \$ 930 as shown in Table 2. Through the results will be disposed of organic waste, wastewater and manure are about 48 kilograms per day for the family which equal to 1440 kilograms per month. The Biogas is produced 0.5 tons of biogas is estimated about \$ 100 in rural areas in the Gaza Strip. It is also produced fertilizers equivalent of \$ 113 per month. So the results and

calculations are clear that the rural family is self-sufficient of biogas, the dispose of organic waste and wastewater and agricultural growth by the fertilizers from the biogas plant.

Recommendations

1. This study focused on the disposal of wastewater and organic waste by building biogas plant for a family in rural areas of the Gaza Strip.
2. It is necessary to operate a biogas plant in rural areas in the Gaza Strip to achieve self-sufficiency in biogas for cooking and lighting.
3. It should support municipalities in the Gaza Strip for this project to support rural families in the implementation of the biogas plant construction.
4. The rural citizens should be instructed by responsible authorities such as the Ministry of Agriculture and Environment on how to build and use a biogas plant.
5. The Ministry of Agriculture and Environment assisted rural citizens in developing agricultural fertilizer production from the biogas plant.
6. Assisting the municipalities in the safety procedures for the biogas plant.
7. Finally, should be set up biogas plants in the Gaza Strip rural and to get rid of organic waste, wastewater and manure and also self-sufficient of biogas. The biogas plant helps in agricultural growth in rural areas and environmental protection.

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