Chapter 1 Biogas Production, through low-cost tubular system for energy in the Tlalmanalco municipality

Capítulo 1 Producción de biogás, por medio de sistemas tubulares de bajo costo, para la generación de energía en el municipio de Tlalmanalco

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Abstract

Biogas is a renewable biofuel product of anaerobic digestion, of the decomposition of organic matter (biomass) generating methane (CH_4) with high energy value that represents 50 and 75% gas, it is an excellent ecological alternative in energy production, in order to take advantage of the biogas production from human and animals generated feces in the municipality of Tlalmanalco in the State of Mexico, a theoretical study was carried out in order to verify how feasible it is to implement a system of tubular biodigesters of low cost favoring the community with the lowest resources, as well as reducing the environmental impact of CO_2 emissions.

Tubular biodigester, Fecal matter, Energy Systems, Biogas, Municipality of Tlalmanalco

Resumen

El biogás es un biocombustible renovable producto de la digestión anaerobia, de la descomposición de materia orgánica (biomasa) generando metano (CH_4) con alto valor energético que representa un 50 y un 75%de gas, es una excelente alternativa ecológica en la producción energética, con la finalidad de aprovechar la producción de biogás procedente de las heces fecales generadas por los humanos y animales en el municipio de Tlalmanalco del Estado de México, se realizó un estudio teórico con la finalidad de verificar que tan viable es implementar un sistema de biodigestores tubulares de bajo costo favoreciendo a la comunidad de más bajos recursos, así como a disminuir el impacto ambiental que se tiene por las emisiones de CO_2.

Biodigestor tubular, Materia fecal, Sistemas energéticos, Biogás, Municipio de Tlalmanalco

1. Introduction

Sometimes organic waste does not receive adequate treatment for final disposal, generating various harmful events, such as the spread of diseases that affect human populations or the transmission of pollutants to environmental ecosystems. Often these wastes from human or animal activities are deposited in vacant lots, rivers, ravines, or open-air dumps, where they generate waste. One way to rescind these affectations is using biogas generating systems, with the purpose of treating waste through controlled anaerobic biological processes, where the result is a biogas rich in methane and carbon dioxide, capable of serving as a biofuel to obtain various benefits. Biodigesters are elementary systems to obtain a biogas with the ideal composition to generate energy. There are several models of biodigesters, some have more advanced technological features, but this research proposes the use of low-cost tubular biodigesters as implementation, to the various problems and theoretical solutions, which are suitable to the social, economic and environmental context of the municipality of Tlalmanalco through minimal investment in materials, installation and maintenance, which is focused on sustainability, promoting long-term benefits throughout the community, especially in areas most lacking in economic resources and services, to directly influence sustainable development.

General Objectives

Analyze the characteristics and energy benefits of low-cost tubular systems, for their future implementation in economically vulnerable areas in the municipality of Tlalmanalco.

Specific objectives

- Determine the sustainable potential of Tlalmanalco, to analyze the projection feasibility of biogas generating systems.

- Energy benefits of tubular systems in the population of the municipality of Tlalmanalco.

Methodology

Several scientific articles on biogas generation focused on low-cost tubular systems were analyzed in order to extract relevant information, with the purpose of making known some characteristics about the sustainable energy potential of these systems in order to promote their implementation, acceptance and benefits in the society of Tlalmanalco.

2 Development and method

Anaerobic digestion

Biogas is a gas that is produced under natural conditions, as well as in places designed and established by man, from a series of metabolic processes generating biodegradation reactions of organic matter, by the action of microorganisms (methanogenic bacteria). In anaerobic conditions (without oxygen) where a mixture of compound gases is obtained, which have the capacity to generate biomass energy made up of methane (CH_4), carbon dioxide (CO_2), and a lower proportion of hydrogen (H_2), hydrogen sulfide. During the fermentation process, various bacterial consortia are required that depend on the energy provided by the substrate, which is essential for the degradation of the matter that is transformed into biomass. Thus, the formation of biogas depends on a fundamental process that takes place through the degradation of organic matter; where biodigestion is an intricate system due to the various chemical and biological changes and the various bacterial microorganisms that interact in the process in a synchronized way. (Lorenzo et. al, 2005; Torres, 2021)

Elementary process biology

Bacterial microorganisms require nutrients extracted from organic matter to break down the polymers found in the macromolecules available in the organic material, and enzymes that they use to degrade the cellular structure to obtain acetic acid. (Leon, 1991). This is subsequently transformed into methane (CH_4) and carbon dioxide (CO_2)

Phases of biodigestion

In 1991 Leon considered that the usual anaerobic degradation process consisted of three main stages for both solid waste or sludge (hydrolysis, acidogenesis, methanogenesis) and two for liquid residues (acidogenesis, methanogenesis). Currently, the 4 stages are considered important for obtaining biodigestion, which are defined below

Hydrolysis: The macromolecules (proteins, carbohydrates, and lipids) are hydrolyzed by means of enzymes that require degrading the cellular structure to obtain simpler compounds such as sugars, amino acids or fatty acids. "Proteins are hydrolyzed into peptides and amino acids by the action of proteolytic enzymes called proteases."

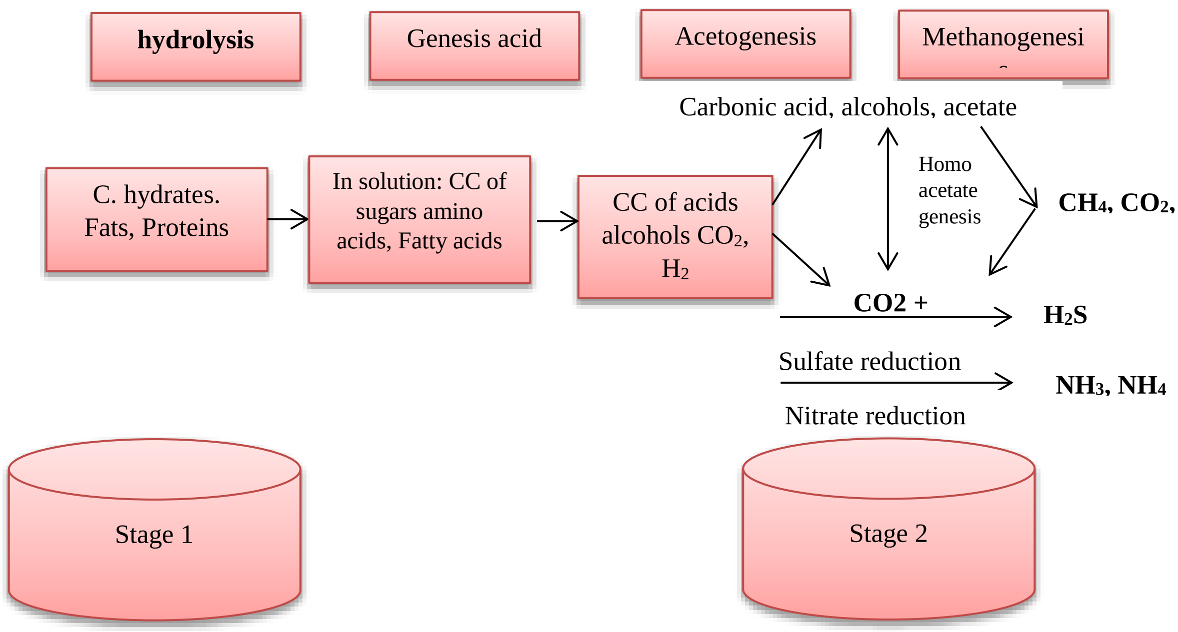
Acidogenesis: The product compounds of the hydrolysis are transformed into acid by means of "soluble molecules that can be used directly by methanogenic bacteria in acetic acid and in smaller organic compounds (propanoicobutyric, valeric, lactic and ethanol)".

Acetogenesis: Compound’s products of acidogenesis are transformed by "acetogenic bacteria, where they are transformed into simpler components, such as hydrogen (H_2) and carbon dioxide (CO_2)".

Methanogenesis: The Archeo methanogenic bacteria generate methane gas, through the metabolization of “monocarbon substrates united by the union of acetate covalent bonds, H_2 /CO_2, format, methanol and some methylamines" and the resulting methane is given mostly by means of acetic acid dexcarboxylation (Varnero, 2011).

In Figure 1.1. the diagram of the fundamental phases that describe the anaerobic digestion process is shown.

Figure 1 Phases of anaerobic digestion (Pérez, 2010)



The phases and main characteristics of the most common bacteria generated during the biodigestion process that interfere in the anaerobic phases are shown in Table 1.1.

Table 1.1 Characteristics of common bacteria in the biodigestion process

Phases	Bacteria	Features
Hydrolysis	*Lactobacillus, Propioni- bacterium, Sphingomonas, Sporobacterium, Megasphaera, Bifidobacterium*	Series of bacteria that are responsible for degrading the complex bonds of macromolecules (proteins, cellulose, lignin, and fatty acids).
Acidogenesis	*Clostridium, Paenibacillus and Ruminococcus*	Bacterial consortium that is responsible for metabolizing "sugars, amino acids and lipids into organic acids, alcohols and ketones, acetate, CO_2 and H_2".
Acetogenesis	*Syntrophobacter wolinii, Syntrophomonas wolfei,*	This bacterial group "fatty acids with 4 to 8 carbon atoms, convert propionic, butyric and some alcohols into acetate, hydrogen and carbon dioxide, which is used in methanogenesis"
Methanogenesis	*Methanobacterium, Methanospirillum hungatii, and Methanosarcina.*	Strict methane-forming anaerobic bacteria, their main characteristic is that they are very susceptible to drastic changes in temperature.

Source: :(Varnero, 2011; Constanza, et al., 2015)

Result of biodigestion

Once the biodigestion process is finished, methane gas (CH_4), carbon dioxide (CO_2), and trace compounds such as hydrogen sulfide (H_2S) are obtained as the main product, and as residues of the organic raw material inside the Biodigester is transformed into a semi-liquid fertilizer, which generates sludge or biol, which are used as a mineralizer for crops and plants. It is important to control some parameters (climatic conditions, altitude, composition of the organic substrate, biological conditions) in order to obtain adequate methane, as well as the various resulting compounds; By not correctly stabilizing the parameters inside the biodigester, the process can be inhibited, obtaining biogas with lower capacity to produce biofuel with little efficiency to generate energy.

Biodigestion process conditions

pH*:* This parameter is important to avoid that the substrate during the anaerobic digestion process goes through acidic and/or basic conditions, the optimal pH quantification should be in the range of 6.5 to 7.5, to avoid inhibition during the process since methanogenic microorganisms are more susceptible to pH variations than any other anaerobic microorganism. (Varnero, 2011; Olaya, *et al*, 2009).

Temperature (T): The temperature for anaerobic digestion processes is a very important parameter, due to the fact that, at the beginning of the biodigestion phase, the bacterial microorganisms adapt to the temperature changes that occur inside the biodigester, if this is not the other case bacterial consortium is in charge of surveying the course to avoid affecting the process. The temperature will determine the retention time for obtaining biogas. At higher temperatures the microorganisms work better, this influences the reduction of the time for obtaining biogas. But if the process is carried out at low temperatures, the microorganisms work less and obtaining biogas takes longer, Varnero indicates that there are three temperature ranges in which different bacterial consortia can work,

Holding time: This is when the process begins with the organic substrate available inside the biodigester, until the anaerobic digestion is completed, thus producing biogas. The retention time depends on the ambient temperature and optimal conditions of the process, therefore the characteristics vary according to the climate of each region, the higher the altitude the temperatures drop steadily, while in regions with lower altitude temperatures increase. The countries farther from the equator, located closer to the poles, have lower temperatures in relation to the countries that are closer to the equator, and that have tropical characteristics such as higher temperatures, the retention times vary as shown in table 1.2.

Table 1.2 N Appropriate retention time for each OM in biodigestion

Environment	Holding time
Psychrophile	> 40
Mesophilic	10 - 40
Thermophilic	<10

Source: Olaya et. al., 2009

Carbon / nitrogen ratio (C/N): Affects the determination of biogas rich in methane and carbon dioxide, the appropriate ratio is between 20: 1 and 30: 1, to make this happen, various materials and/or substrates must be incorporated to achieve an adequate balance, carbon and nitrogen they are essential for the essential life of methanogenic microorganisms (Olaya et. al, 2009; Mori, 2021).

Solid / liquid ratio: It is important to maintain adequate humidity inside the biodigester, so that the fecal matter mixes perfectly and anaerobic digestion takes place. Table 1.3 shows the solid-liquid relationship of some fecal materials.

Table 1.3 Ideal solid-liquid mixture of the most common fecal materials

Manure	Solid: Liquid Ratio
Cow	1: 3
Pork	1: 4
Llama / Sheep / Guinea Pig	1.8-9

Source of consultation: Martí, 2019

Inhibition factors: Compounds (volatile acids, ammonia, nitrogen, agrochemicals), of a toxic nature present during the process, which alter the metabolism of the microorganisms and kill the bacteria, interrupting biodigestion. The maximum permissible amount in concentration that the biodigester must contain of the various compounds is shown in Table 1.4.

Table 1.4 Maximum allowable concentration of compound in the biodigester

Inhibitor Compound	Inhibiting Amount
Sulfates	5000 ppm
Sodium chloride	40,000 ppm
Nitrate	0.05 mg /mL
Copper	100 mg/L
Chrome	200 mg/L
nickel	200-500 mg/L
ABS (synthetic detergent)	20-40 mg/L
sodium	3500-5500 mg/L
Potassium	2500-4500 mg/L
Calcium	2500-4500 mg/L
Magnesium	1000-1500 mg/L

Source of consultation: Canales, et. al., 2010

Biogas: It is a gas that is produced in natural conditions, as in places suitable for man, where biodegradation reactions of organic matter originate, by the action of microorganisms (methanogenic bacteria), in anaerobic conditions (without oxygen), where a mixture of compound gases is obtained, which have the ability to generate biomass energy, consisting of methane (CH_4), carbon dioxide (CO_2), and to a lesser extent hydrogen (H_2), hydrogen sulfide. It is understood as an essential process within the organic matter cycle. Table 1.5 shows the composition of biogas as reported by Varnero in 2008.

Table 1.5 Biogas composition

Composition	55 - 70% methane (CH_4) 30 - 45% carbon dioxide (CO_2) Traces of other gases
Energetic content	6.0 - 6.5 kW h m^3
Fuel equivalent	0.60 - 0.65 L oil / m^3 biogas
Explosion limit	6 - 12% biogas in the air
Ignition temperature	650 - 750 ° C (with CH_4 content mentioned)
Critical pressure	74 - 88 atm
Critical temperature	-82.5 ° C
Norm density	1.2 kg m^{-3}
Smell	Rotten egg (the smell of desulfurized biogas is imperceptible
Molar mass	16,043 kg $kmol^{-1}$

Source of consultation: Varnero, 2011

Chemical compounds CO_2, N_2, O_2, NH_3, H_2S and their effects on biogas

Carbon dioxide (CO_2) is an essential gaseous component for the formation of methane in the biogas generation process, it is necessary to adequately control CO_2 in order not to acidify the course. It is important to homogeneously disperse the substrate inside the biodigester to improve anaerobic degradation.

Nitrogen (N_2) and oxygen (O_2) are found in a 4-1 ratio in the aeration stages and have the function of expelling hydrogen sulfide (H_2SO_4).

Ammonia (NH_3) is regularly found in minimal quantities (<0.1 mg/m^3) when the organic material used comes from bird droppings and some wastes, which increase the amount of the maximum compound by (1.5 mg/m^3). Exceeding these permitted levels can cause damage to combustion engines.

The presence of hydrogen sulfide in the biogas must be controlled and reduced, since this is a very corrosive acid that damages the components of the biodigesters (piping, valves, etc.). It is important to control the filters to avoid damage to the machinery or turbines used in the conversion of biogas into energy (Pérez, 2010).

Biogas and power generation

Biogas has an important potential to produce heat energy, due to the presence of methane gas (CH_4), which is the main component since it is found in concentrations of 40 to 50%. Even though carbon dioxide (CO_2) is the second gaseous compound present during biodigestion, it is produced in large quantities, so it must be controlled to prevent it from reducing the heat capacity of the biogas, to achieve good combustion. There are other trace compounds in small concentrations of 2% in the biogas composition such as hydrogen (H_2) and hydrogen sulfide (H_2S).

The energy generated by biogas has various energy uses.

- It can be used directly to generate lighting or to heat food through special stoves.
- It is used as a heater inside homes or for livestock use to heat animals in the production process.
- It is used as a fuel to power machinery by means of specialized combustion engines or turbines to generate electrical energy, which can be transmitted to the electrical grid.

That is why many researchers have carried out various studies to obtain biogas for energy use, at the Universidad Nacional Agraria la Molina in Peru, (Torres,2021) carried out an investigation on the way to collect feces from different animals existing on campus annually During the period from 2008 to 2018, collecting 7397 kg / day of various livestock waste, thus obtaining 745 Mwh / year, carried out various physicochemical analyzes (pH, electrical conductivity, density, humidity, ash, calorific value, etc.) derived of the quartering method during the obtaining of the sample, relying on the general equation of the gases they were able to calculate the energy potential, to determine the amount of biogas generated, reached the conclusion that manure of equine and bovine origin generate a greater amount of energy than the feces of poultry and other species in table 1.6, the results obtained from the energy capacity in the generation of biogas in the various substrates are shown .

Table 1.6 Energy capacity for the generation of biogas on various substrates

	Methane (m3 /year)	Energy capacity (MWh/year)
Cattle area	111235.2	1104,565
Poultry area	16448.96	163.3382
Equine area	7490.67	74.38244
Minor species	1995.71	19.8174
Sheep and camelids	6030.46	59.88213
Pig area	71758.72	712,564
-	-	2134.59

Reference Source: Torres, 2021

Environmental benefits of biogas

Biogas reduces deforestation in rural areas and avoids dependence on fossil fuels and electricity. In addition to reducing carbon dioxide and greenhouse gas (GHG) emissions, through the generation of biofuels, which are produced from the natural decomposition of biomass (organic waste). This type of energy reduced in polluting gases is known as renewable energy. (Weber, *et al*., 2012).

The promotion and implementation of projects of biogas generating systems is a form of treatment to reduce methane emissions, which generate organic waste, mainly excrement that is emitted into the atmosphere and contributes to part of the greenhouse effect. "Methane contributes 20% to the anthropogenic greenhouse effect. Among the sources of methane of human origin, more than 50% corresponds to livestock and up to 30% comes from rice cultivation " (Varnero, 2011). Biogas, due to its methanogenic characteristics, has the possibility of producing electrical energy through anaerobic digestion, where the final product is a biofuel that can be used to generate various types of energy.

- Heat energy: using a stove
- Electric power: light, some appliances
- steam: generates energy in different types of machinery

Advantage

- It helps to generate sustainable energy, mainly in dispersed rural communities of extreme poverty, where public electricity facilities are often lacking.
- Reduces CO_2 and other types of polluting gases
- Economic cost
- Generation of fiscal stimuli (green bonds)

Biodigesters

They are sealed containers, designed in order to perform anaerobic degradation processes generated by decomposition, different substrates can be used to fill them, such as animal excrement, sewage and vegetable waste, etc. They have the purpose of generating methane-rich biogas (Avila, 2016). The construction materials are usually varied depending on the climatic conditions, the height of the installation site, the type of soil, budgets, usually "concrete, polyethylene and concrete are used. A biodigester is made up by.

Cargo tank: It conducts the organic matter through a tube generally made of materials resistant to high pressure, towards the center line of the tank.

Gas storage tank: Consists of a circular or square brick construction with a polished concrete finish and a sturdy material bag, is used in the globe digesters. These materials serve to retain the gas in a thermal way so that when availability is required, it can be used.

Discharge tank: It is the part of the pipeline where residual sludge is extracted, generally these sludge are used as fertilizer due to its mineralization characteristics in crops or plants.

Driving line: Quantity of gas to be transported, and the distance between the places where the different processes take place in which plastic, copper or metallic piping is used, depending on the characteristics of the project, as well as the environmental conditions to be determined.

Valves: Two valves are required for the gas, the first will be installed at the beginning of the process and the second at the end of the outlet line, must be made of resistant materials such as PVC or stainless steel.

Traps: The gas must be eliminated from impurities such as sulfuric acid, this in order not to damage any part of the system that does not have the resistance to withstand this type of corrosive compound. (Corona, 2007).

Classification of biodigesters

There are various types of biodigesters, the most common being of the "horizontal and vertical type and of the continuous, semi-continuous, discontinuous" type. (Pascual, *et al*, 2011)

Laptops: They are simple biodigesters that are used in domestic activities, they are built of resistant materials but easy to transport.

Continuous flow: It is one that "allows the continuous transport of organic matter, mainly in vertical digesters, they are used in large-scale projects and have high-tech instrumentation such as agitators and heating."

Semi-continuous flow: They are loaded in short periods of approximately 12 hours, 1 time every 24 hours or every 48 hours, the available load of organic raw material is used constantly on a daily basis. The 3 most common digester models that have the semi-continuous flow feature are Indian, Chinese, and Taiwanese. These digesters are used mainly in rural areas.

Discontinuous flow: The organic matter is loaded and unloaded until the end of the process, it is removed when the gas generation stops, only then can the digester be reloaded, the duration of the process depends on the temperature and the "retention time, in usual conditions the process can last between 2 and 4 months " (Avila, 2016). In the table 1.7, conventional biodigesters are shown.

Table 1.7 Main conventional biodigesters

Biodigester	Characteristics	Advantage	Disadvantages
Floating dome (Hindu)	It is buried vertically in what appears to be a well, its structure has resistant materials such as brick or concrete. This digester has a floating hood that regulates the gas pressure and that rises and falls depending on the volume exerted.	Simple systems to understand. Constant gas pressure.	High construction and maintenance costs.
Fixed dome (china)	They are generally cylindrical containers, which are constructed of resistant materials such as concrete, cement or concrete.	Long lasting time. Withstands drastic weather changes.	Fragmentation of the material due to high internal pressures. For its construction it requires skilled labor.
Tubular Biodigester (Taiwanese)	Regularly, the material used for its construction is polyethylene (PE), or geomembrane (PVC), it has a horizontal tubular shape and is half buried in a trench, to adapt the biodigester in a fixed and safe position.	Accesible price. It is portable and can be easily placed in any difficult access place	Short life time. Breakages due to drastic weather changes (solar tent must be used)

Source of Consultation: Avila, 2016

Tlalmanalco municipal context

Tlalmanalco de Velázquez is a municipality located in the eastern part of the State of Mexico, with the following coordinates 19º 80 '48" and 19º 15' 43" of north latitude and 98º 37 '58" and 98º 51' 20" of west longitude. It is adjacent to the municipalities Puebla (West), Chalco (North), Ixtapaluca and Cocotitlán (West), Amecameca, Ayapango and Tenango del Aire (South). The municipality has a current population of 51,804 inhabitants and a territorial extension of 158 km^2, "due to its extensive forest areas, the municipality focuses on the provision of environmental services such as the maintenance of biomass for carbon capture and the provision of oxygen" (Cervantes, 2011). The general aspects of the municipality of Tlalmanalco are shown in table 1.8.

Table 1.8 General aspects of the Municipality of Tlalmanalco

Important aspects (SAE) of Tlalmanalco	General data
Coordinates	19º 80 '48 "and 19º 15' 43" of north latitude and 98º 37 '58 "and 98º 51' 20" of west longitude
Total population (2021)	47,390 inhabitants
Area Km^2	158.58 km
HDI (2015)	0.779%
Poverty (2015)	22,833 inhabitants
Altitude	2400m
GDP (2017)	1253.4
Climate	Temperate coniferous forest
Rural population (2010)	7,746 inhabitants

Source of consultation: Municipal Development Plan Tlalmanalco, 2019

In Figure 1.2, the location of the municipality of Tlalmanalco, obtained via satellite with the support of Google Maps, is shown in a red circle, in order to identify the area where it is intended to install biodigesters to supply the most vulnerable community that do not have service of energy, using low-cost and environmentally friendly energy, in addition to minimizing health illnesses experienced by the population due to poor disposal of feces generated in the municipality.

Figure **1.2** Satellite location of the municipality of Tlalmanalco State of Mexico

Reference source: Google maps, 2021

2030 Agenda for the development of renewable energies

The 2030 agenda is a plan with 17 objectives and 169 goals that will be applied over the next 15 years in order to achieve sustainable development, reducing economic, social and environmental deficiencies. (PNUM, 2019)

Social pillar: Is in charge of analyzing the social and economic conditions required by the families of Tlalmanalco to reduce vulnerable characteristics and social inequality, in order to improve human life. This indicator is measured based on the HDI.

Population: Population: In 2015 Tlalmanalco had a population of 47,390 inhabitants. (Planning Unit of the Municipality of Tlalmanalco, 2019). Table 6, shows the statistical data recorded from the population and housing census in the year 2010 and 2015, regarding the number of inhabitants increased by 1,260 in just 5 years as shown in Table 1.9 almost 0.90% which is remarkably little, however, with this increase more public services are required among them the energy supply.

Table 1.9 Population and Housing Census 2010.

Year	2010	%	2015.	%
Men	22,333	51.78%	22,517	47.51%
women	23,797	51.58%	24,873	52.48%
Total	46,130	100%	47,390	100%

Consulted source: Planning Unit of the Municipality of Tlalmanalco,2019

Poverty: In 2015 Tlalmanalco had 22,833 poor inhabitants, 45.6% of the total population. *Planning (Unit of the Municipality of Tlalmanalco,2019),* (see table 1.10). As can be seen in the table, the number of inhabitants with indices of poverty, moderate poverty and extreme poverty represents almost 91.2% of the population reported by IGECEM in 2015, it is a seriously alarming figure since only 8.8% of its population it can lead a moderate life, which is why this project is aimed at designing and placing biodigesters and supplying energy to the community.

Table 1.10 Tlalmanalco Poverty Report

	Year 2012			Year 2015		
Indicators	**Population**	**%**	**Average deficiency**	**Population**	**%**	**Average deficiency**
Poor population	17,903	41.7%	2.4	22,833	45.6%	2.0
Population with moderate poverty	15,484	34.5%	2.1	19,897	39.7%	1.8
Population with extreme poverty	2,420	6.9%	3.7	2,936	5.9%	3.4

Reference source: Planning Unit of the Municipality of Tlalmanalco. (2019)

Public service housing: The home is the main pillar where the family develops and tasks that influence other social factors are carried out. Understanding the conditions in which the population lives and the services that are provided in a private way or through the Government are of great importance to know what percentage of the population such services in table has 1.11, the data reported by INEGI are shown from the years 2010 to 2015.

Table 1.11 Public Housing Services

Availability of public services in Tlalmanalco		Year 2010		Year 2015	
Households	occupants	Households	Occupants	Households	occupants
Total		11,315	45,599	12,047	47,390
Tubing water					
Have		10,918	43,983	11,875	46,716
They do not have		378	1,509	125	490
Not specified		19	67	47	184
Sewer system					
Have		11,064	44,616	11,803	47,115
They do not have		226	856	122	63
Not specified		25	87	122	212
Electric power					
Have		11,263	45,389	11,976	47,115
They do not have		37	122	16	63
Not specified		fifteen	48	55	212

Consulted source: Planning Unit of the Municipality of Tlalmanalco, 2019

HDI: The human development index is an indicator that determines the economic wealth, as well as the quality of life in a country or an established region, where rigorous aspects are determined to complete a high HDI. Tlalmanalco has a high HDI, its range is determined in an approximate of 0.692 to 0917, (Unit of the municipality of Tlalmanalco, 2019).

As can be seen in Table 1.12, in the health system it has 78.6%, in education 73.5%, income 69.8%, although it is not a municipality with a low HDI, it does require to have better human health quality and better economic income

Table 1.12 Huma0n development index (HDI)

	Health	Education	Entry	HDI
Tlalmanalco	0.786	0.735	0.698	0.739

Source consulted: Planning Unit of the Municipality of Tlalmanalco, 2019

Economic pillar: In the municipality of Tlalmanalco, management systems that favor wealth, social values and respect for the environment must be adapted to obtain sustainable development; therefore, when implementing and using biodigesters for the supply of energy, it will favor its economic income.

GDP: The gross domestic product is an indicator of the economic growth of a population, which is acquired through goods and services completed in a set time (see table 1.13). "Tlalmanalco in 2017 had an approximate GDP of 1,254 million pesos". (*Planning Unit of the Municipality of Tlalmanalco, 2019).*

Table 1.13 Gross domestic product of the municipality of Tlalmanalco (GDP)

GDP of Tlalmanalco		
Economic activity sector	**2016**	**2017**
Agriculture, animal husbandry and export, forestry, fishing and home	37.8	48.3
Industry	630.3	637.9
Mining	0.9	1.8
Generation and transmission of electrical energy	35.1	34.4
Manufacturing industry	586.8	595.3
Services	346.5	511.3
Shops	99.5	148.0
Educational services	23.3	34.4
Health and social assistance services	4.8	8.9

Consulted source: Planning Unit of the Municipality of Tlalmanalco, 2019

Tlalmanalco is characterized by being a municipality that is mainly dedicated to the manufacturing industry**,** where the main objective is to reduce poverty in the municipality's labor society.

Environmental pillar: Seeks the care of the environment and the proper use of natural resources, it is essential to supply economic and social needs in a conscious way. Renewable energies are essential to plan a present and a future, which avoids the depletion of non-renewable resources.

Tlalmanalco is a semi-rural municipality that has large extensions of natural areas, as well as diverse flora and fauna, since the municipality locates a large part of its territory in the area of the "Iztaccíhuatl-Popocatépetl snow-capped area". *(Planning Unit of the Municipality of Tlalmanalco, 2019).* Table 1.14 shows the environmental characteristics of the municipality

Table 1.14 Environmental characteristics of the municipality of Tlalmanalco

Indicator	Characteristics	Importance
Climate	Temperate subhumid characterized by having an average annual temperature of 13.2 ° C winter = 10.9 ° C Spring = 15.4 ° C	Climate is essential for optimal growth and development of flora and fauna. Weather disturbances
Flora	Coniferous forest and oaks etc.	Flora and fauna are essential for their incalculable value because they provide balance in ecosystems and are important as natural resources for human survival.
Fauna	Squirrels, gophers, rat's opossum, rabbit, bat, rattlesnake, various types of birds (swallows, crows), and insects.	
Ground	In the Iztaccíhuatl area, the soils are made up of volcanic ash and pumice. Where various soils are constituted, such as andosols, lithosols, cambisols and flurisols	Tlalmanalco has a land area of 15,857 hectares that are mainly provided for the use of forestry, occupying 72. 47%% of the surface, therefore, agricultural use occupying 20.09%.

Hydrography	Sub-basin the company. Micro-basin of San Lorenzo Tlaminilolpa San Rafael micro-basin	Water is a primary resource for the development of activities and survival of the inhabitants of Tlamanalco. For this reason, responsible use is essential, to avoid contamination, damage to bodies of water.
Forest resources	Tlalmanalco has 10,600 hectares of forest occupying more than 50% of the total area.	Forest resources are generally used as raw material to transform cellulose into paper, or as fuel to heat food. Uncontrolled degradation and deforestation are a matter of great concern for the inhabitants of Tlalmanalco

*Consulted source: (*Zamorano, 2009; *INAFED, 2010; Planning Unit of the Municipality of Tlalmanalco, 2019)*

Low cost biodigester

Low-cost biodigesters have been stablished in developing countries since the 1980s. The first model to be implemented was the red mud PVC, later several flexible tubular models were developed, leading to the development of several low cost biodigester models, they lack complex technological systems (stirring and heating systems), and that are adapted to the use of cheap and easy-to-transport materials, to satisfy the demand in rural populations that do not have the necessary sanitary sanitation services, and/or the lack of a comprehensive waste management system (SIGR). They are ideal for domestic use in small farms (agricultural), and/or for the treatment of fecal waste and urine with the use of latrines, In order to obtain biogas that can be used as bioenergetics, they also help prevent the transmission of diseases from the mismanagement of waste spread during the volatilization of pathogenic materials that are transmitted to human beings; That is why these biodigesters help to carry out a comprehensive and controlled treatment of waste, whether of agricultural and/or human origin (Martí, 2019).

Its implementation and use are a good alternative to reduce the consumption of firewood in the kitchen and stop producing high amounts of carbon dioxide (CO_2) that affects the respiratory tract, causes headaches, causes seizures and in extreme cases death, in addition to reducing the physical work of the peasant, thus avoiding long-term diseases caused by poor posture or excessive load. This technology allows the control of the biodigestion process avoiding the transmission of infectious microorganisms from organic waste, since feces of animal and human origin contain various pathogens that cause alterations in human health, which are shown in table 1.15. Providing with this, welfare of the population, having clean energy helps the family economy.

Table 1.15 Pathogens that may be present in stool and associated symptoms

Group	Pathogens	Symptoms
Bacteria	*Aeromas spp*	Enteritis
	Campylobacter jenuni / coli	Camylobacteriosis, diarrhea, colic, abdominal pain, fever, nausea, arthritis, Gullain syndrome, Barre
	Eschererichia coli (EIEC, EPEC, ETEC, EHEC)	Enteritis, with the EHEC variety, there may be even fatal internal bleeding
	Salmonella typhi / paratyphi	Fever, typhoid / paratyphoid, headache, fever, malaise, anorexia, bradycardia, splenomegaly, cough
	Salmonella pp	Salmonellosis, diarrhea, fever, abdominal colic
	Shingella spp	Shingellosis, dysentery (bloody diarrhea), vomiting, colic, fever, Reiter's syndrome
	Vibrio cholera	Cholera, acute diarrhea, fatal if severe and untreated
Virus	*Adenovirus*	Various respiratory problems, some varieties attack the intestines
	Enteric adenovirus, type 40 and 41	Enteritis
	Hepatitis A	Hepatitis, fever, malaise, anorexia, nausea, abdominal pain, jaundice
	Rotavirus	Enteritis
Protozoan parasite	*Cryptosporidium parvum*	Cryptosporidiosis, acute diarrhea, abdominal colic, pain
	Cyclospora histolytica	Diarrhea, abdominal pain
Helminths	*Ascaris lumbricoides*	Usually without symptoms, sometimes wheezing, fever, enteritis, pulmonary eosinophilia
	Taenia solium / saginata	Taeniasis
	Trichuris Trichura	Trichuriasis, without symptoms or general digestive upset, wasting with dry skin and diarrhea

Source consulted: Strande, et al., 2014

The installation of biodigesters represents various social challenges, such as the recycling of organic waste, which allows obtaining biogas, this is not entirely accepted by diverse groups of inhabitants for reasons of religion that does not allow the handling of animal fecal matter and/or stigma**,** they do not share the use of these systems. In order to implement these low-cost structures and educate populations that are not interested in the subject, it is necessary to disseminate and design procedures within communities so that they can see how they work.

Although the design of the project is essentially good, the consumer must be constant in the maintenance of the scheme so that the obtaining of biogas is adequate, if the necessary care is not taken, the project can fail with a great economic loss and if the biodigester is not dismantled It can cause contamination in the area it is located, unfortunately in Mexico projects of this type have been abandoned due to lack of economic resources or of interest on the part of the population or municipalities.

Regarding the governmental and management aspects, should consider planning improvements in obtaining energy and fuels through the implementation of technologies that are friendly to the environment and that are accessible to all the inhabitants of Tlalmanalco. In the case of low-cost tubular biodigesters, the Government and society as a whole will have to adapt to new changes in the management systems, to obtain mutual benefits, giving way to a future that is adapted to the needs of clean energy, to ensure the precepts of the 2030 agenda, achieving the use of biomass in biogas generation supporting sustainable development.

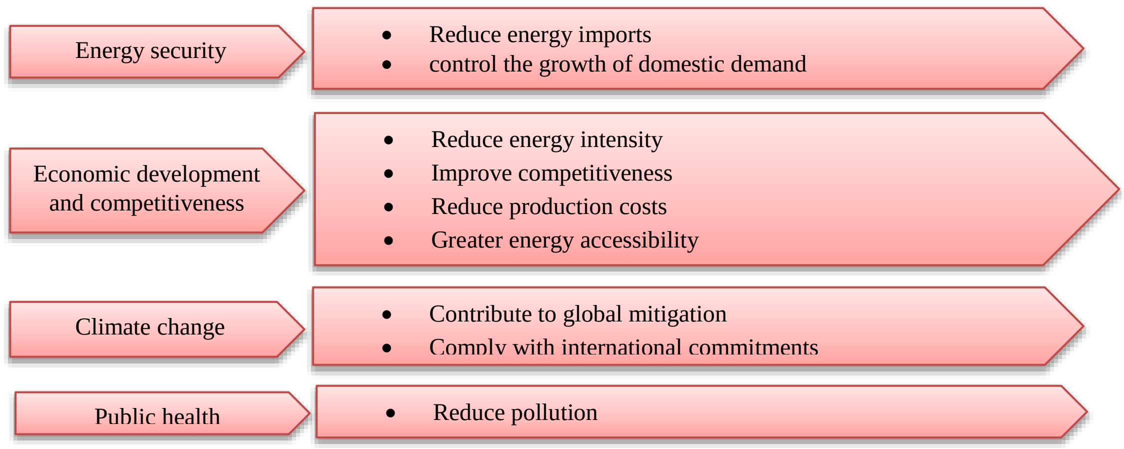
In Figure 1.3, the main aspects that allow promoting the energy generation are shown not only in the municipality of Tlalmanalco, but in the entire Mexican Republic in a gradual and gradual manner. Energy management currently in Mexico is used for the generation of light in areas that do not have lighting in order to obtain heat in cool places, and/or to be able to travel long roads, without any fatigue, with the use of fuels. The use of fuels for the generation of energy represents a great economic investment for society worldwide, another means of obtaining energy is through deforestation from where they obtain the raw material (wood, pulp for paper) caused there is an uncontrolled logging generating degradation forest and soil, as well as the loss of biodiversity; For this reason, viable alternatives are being sought to curb climate change.

Due to the aforementioned, the appropriate use of biogas allows reducing the deforestation of green areas, as well as greenhouse gas emissions (carbon dioxide (CO_2), methane (CH_4), which are found naturally and can be generated during emission and/or volcanic eruption; but for the most part they are emitted into the atmosphere by the various anthropic processes carried out by man, mainly derived from industry or fossil fuels that, when emitted into the environment, cause alterations in temperature worldwide.(Gómez, 2012).

In Mexico, political elements have been implemented to invest less energy resources, such as the Official Mexican Standards on energy efficiency, where reference criteria are established for consumers, support for help, and the reduction of energy consumption in public sectors, good habits, and energy incentives, fundamental in the energy management system, thus promoting responsible energy consumption in the population. It is proposed that Mexico meet various objectives to reduce greenhouse gases (GHG) gradually or definitively, setting the goal of 2050, if it is possible to implement energy management adequately and hierarchically, industries will obtain a considerable reduction in the cost of energy transformation, (Hernández, *et al*., 2014).

Worldwide there is great concern in solving the problem of greenhouse gas emissions, so on December 11, 1997, the international protocol of Kyoto was signed by 84 countries, exhorting companies to emit 1 ton of CO_2 or avoid its total emission, companies that exceed this established limit will be financially sanctioned by the government, while companies that comply with the agreement will receive an intangible bonus for avoiding the emission of said gases (Gómez, 2012).

Figure 1.3 Boost scheme energy management



Source consulted: Hernández, et al., 2014

The design and implementation of this type of project must be carried out by people specialized in the area and have the necessary knowledge to obtain favorable results, during planning the first thing to be done is to choose the correct area to make the trench where the pipe will be installed. biodigester for this, the following points must be taken into account:

– The installation should not be carried out in areas close to flammable material, nor removed from the house (do not use unnecessary material)
– Do not place in an area where infants usually carry out their activities, or muddy areas where the earth can cause landslides.
– Delimit the area with bars or obstacles to avoid any accident.
– If its usefulness is predetermined for the use of stoves, it is important to place it with an unevenness with respect to the kitchen, this because the gas flows better from the bottom to the top.

The generation of biogas has taken a great boom in recent years worldwide, among the most recent investigations are those carried out by Chasquibol that has focused on the realization of new procedures in the generation of biofuels focused on the biorefinery and the inputs products of the biomass of algae, carrying out a qualitative analysis of these; as well as investigating informative aspects regarding the transformation of cell extraction and disruption to obtain macromolecules; Sierra and collaborators focused their research to analyze and characterize a multiple tubular biodigester in which six blind treatments were carried out, with different short retention times (5 to 8 days), with a determination of excrement and water (1:4, 1;7,1;10), from swine wastewater from the Agricultural Educational Institution Guacavía in the Municipality of Cumaral in Colombia.

For the subtraction of the organic substrate, various mathematical and statistical calculations were performed, using calculations and software, required to analyze various physicochemical parameters (HRT, excrement: water ratio, BOD sample, COD, TSS, TSS, SSV and temperature), thereby achieving, establishing an efficient procedure in the removal of organic matter for the generation of biogas, the results obtained in their research are shown in table 1.16 (Chasquibol, 202; Sierra, *et al*, 2021).

Table 1.16 Results of organic material subtraction derived from swine wastewater

Parameter (Mg/L)	Subtraction efficiency %
BOD	84.95
COD	88.74
Ssed	84.48
TSS	81.04
SSV	86.50

Source consulted: (Sierra, et al, 2021)

Other researchers focus their research on biogas purification processes theoretically in a physicochemical and biological way using microalgae which have been shown to have great efficiency in the removal of carbon dioxide and hydrogen sulfide in a percentage of 90 to 100% with little environmental impact. In the city of Celedin, Peru, the researcher Mori designed and assembled a tubular sleeve biodigester with a capacity of 7.2 m^2 and 5.7 m in length in order to eradicate a large amount of solids from waste effluents from a slaughterhouse in the same region, thus achieving the removal of materials of meat origin, within his research he carried out physicochemical analyzes, BOD, COD and SST, which allowed him to verify the elimination of residual meat effluent (De la Caridad, et. al., 2021; Mori, 2021).

Table 1.17 Parameters for the eradication of solids generated by residual effluents from a slaughterhouse

	Time in days	% BOD eradication	% total removed
Biological oxygen demand	Four. Five	52.45%	83.17%
	180	99.72%	
	Time in days	% COD eradication	% total removed
Chemical Oxygen Demand	Four. Five	73.00%	86.57%
	180	98.98%	
	Time in days	% BOD eradication	% total removed
Total Suspended Solids	Four. Five	94.73%	95.09%
	180	99.17%	

Source consulted: (Mori, 2021)

The research carried out on the benefits in the use of biodigesters to avoid the emission of GHG, carrying out an adequate comprehensive treatment, in this research the feasibility of installing low-cost biodigesters in the municipality of Tlalmanalco is sought, this being a municipality with a wide environmental importance, since it is considered "a lung for the area of the valley of Mexico" (Cervantes, 2011). In recent yearsthe physical expansion of Mexico City and the State of Mexico has generated a transcendental demographic growth. This growth leads to a greater demand for goods and services that have led to the industrialization of the agricultural sector and various industries.

These processes require electrical energy or fuels in order to carry out the transformation and distribution of the product. Fossil fuels like gasoline, diesel, and natural gas, etc. (From the fossilization of coal for thousands of years). They are considered polluting and inefficient energy generators, not only generalizing the emission of GHG in the atmosphere (CO_2, CH_4, NO_X), but also the extraction and transformation that these fuels require produces great environmental impacts, such as the loss of natural areas and biodiversity, in addition to requiring excessive consumption of the electrical network. “Tlalmanalco has 10,611 hectares of forest that represent more than 50% of the total forest area, a situation that is currently aggravated by poor forest management and profitable activities. Uncontrolled deforestation, pests and diseases, and poor land use have reduced the forest area. (Planning Unit of the Municipality of Tlalmanalco, 2019). Unlike fossil fuels, biogas is a renewable energy that depends on biomass of organic origin, this can be obtained naturally, in a residual way and as an energy crop, so that the available substrate can ferment and degrade from anaerobically in the biodigester and a minimum biogas with "55% methane" is obtained,

Low-cost biodigesters are ideal in the municipality of Tlalmanalco, to transport it to homes in hard-to-reach alpine areas. Low-cost tubular biodigesters are often constructed of lightweight materials that can be easily and compactly transported to avoid unnecessary transportation costs.

This digestor system focuses on the most economically vulnerable populations that lack some good or service, such as the lack of electricity, not having gas for cooking. In Tlalmanalco, poverty is divided into three aspects, which are the following.

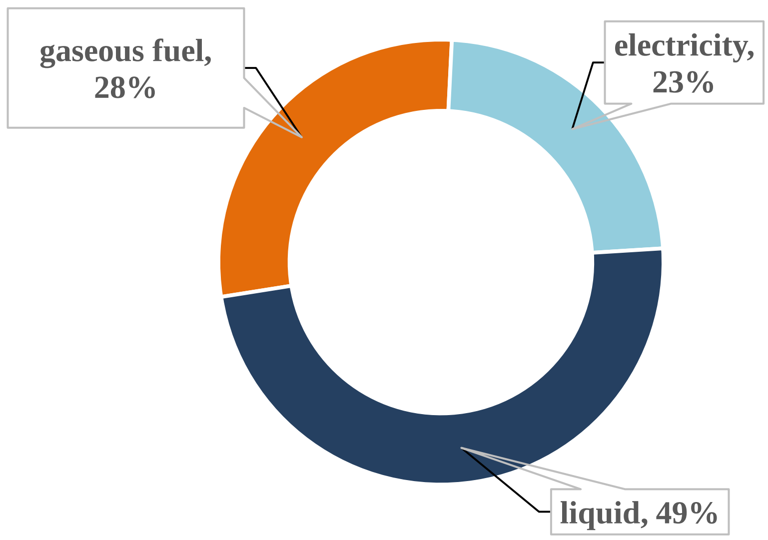
Vulnerable with deficiencies refers to the population that, due to some vulnerable situation such as a disease, does not have the means and services to sustain itself adequately. 11,104 people have this condition in Tlalmanalco.

Moderate poverty: has poverty, but still has income. 19,897 people have this condition in Tlalmanalco.

Extreme poverty: population with lower income capacity 2936 people have this condition in Tlalmanalco. (CONEVAL, 2015).

Low-cost tubular system materials are generally sought, which are reused or moderately priced, so that the entire population can have access to these systems and obtain benefits for sustainable development. In graph 1.1, the percentage of energy fuels used in the municipality of Tlalmanalco is shown, among which are gaseous fuels with 28% of use, electricity 23% and liquid with 49%, these data allow to corroborate that it is necessary implement the use of biodigesters to reduce carbon dioxide emissions to the environment.

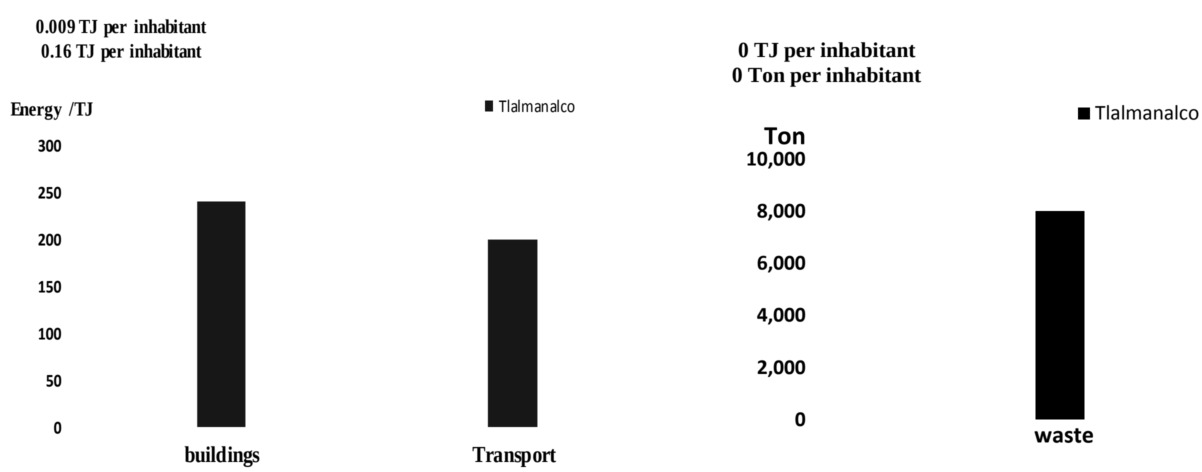
Graph 1.1 Percentage of energy fuels in the municipality of Tlalmanalco



Reference source: Global Covenant of mayors for Climate & Energy, 2019

In graph 1.2, the energy required per inhabitants of the municipality of Tlalmanalco in buildings, transportation and waste generation is shown, having 0.009 TJ per inhabitant that is required in buildings and 0.16 TJ in transportation, as well as 0TJ in the energy used in the waste generated per inhabitant per year.

Graph 1.2 Energy consumption (Buildings and Transportation), and waste generation in 2016 in the municipality of Tlalmanalco



Source consulted: (Global Covenant of mayors for Climate & Energy,2019)

3. Results

By implementing biodigesters in the beginning of Tlalmanalco, it is expected in the short term to have the following aspects as favorable results:

Energy generation: Generates biofuel (biogas), "very similar to butane and propane gas. It can be used for the use of stoves, heating, lighting "

Production: The biol that is produced at the end of the biodigestion process is a fertilizer that has the ability to mineralize through nutrients. This fertilizer can be deposited directly to crops or seeds "improving their yield by 30%"

Family health: Unlike other fuels that emit harmful gases, the biogas used controls harmful gases such as CH_4 and CO_2

Animal hygiene: Bad odors are controlled and diseases generated by vectors (flies and other rodents) are avoided

Environment: "By generating each family their own cooking fuel, deforestation can be gradually reduced." As well as reducing the use of fossil fuels.

Workload and economy: "The time that is invested in obtaining firewood or the expenses in the purchase of fuel " it is replaced by the obtaining of available excrement, which is introduced into the biodigester to begin the biodigestion process and the future obtaining of biogas.

Sustainable technology: Being a technology that avoids the unfavorable use of natural resources, low cost, accessible use and little maintenance, it is considered a sustainable energy

Low cost: The cost of a family biodigester can be variable, depending on the size of the project and the climate. But it is defined that a medium biodigester can cost between 150 and 200 US dollars (Martí, 2021).

4. Acknowledgments

To the Tecnológico de Estudios Superiores del Oriente del Estado de México for providing all the facilities to carry out this research.

5. Conclusions

The theoretical study carried out on the municipality of Tlalmanalco, in terms of geographical area, as well as the most vulnerable areas, the services it has and the energy expenditure it has per inhabitant per year; allows observing that even when there are no statistical data from INEGI, IGECEM for recent years, this municipality has the characteristics and adequate spaces to implement a low-cost tubular biodigester system, greatly favoring the economic energy costs of the community, at the same time, the diseases generated by the various pathogens found in feces that are still exposed to the environment will be reduced, since many houses have latrine systems, there will also be a decrease in carbon dioxide emissions (CO_2)generated favoring the care of the environment.

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