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Livestock Biomass: Energy source for 26 municipalities in Hidalgo State experiencing high marginalization

Biomasa ganadera: Fuente de energía para los 26 municipios de alta marginación del estado de Hidalgo

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Abstract

The high consumption of natural non-renewable resources has caused an exponential increase in the greenhouse gases which provoke global warming and as a result, every country on the planet suffers environmental issues due to the excessive use of fossil fuels. There are several different sources of gas production, principally caused by human beings, however there is little to no interest in mitigating them. Global interest is instead currently focused on containing them via the reduction of carbon dioxide (CO_2) and methane (CH_4). In the Paris Agreement, participating countries have committed to keeping the rise of the mean global temperature below 2 °C and to limiting its increase to 1.5 °C. Latin America as a whole (and principally, Mexico) has committed to lowering greenhouse gases 25% by 2030 and 50% by 2050 (AZEL, 2018). To achieve this, it is necessary to contribute by applying clean energy alternatives. The current project proposes using bovine and swine organic wastes for the production of biogas and electric energy in 26 cities of high marginalization in Hidalgo, a state in Mexico which contributes to lowering environmental pollution, providing access to better services for raising the quality of life of its inhabitants, and minimizing the use of (therefore saving the money provided for) subsidies for conventional electric energy.

Biofuels, Biogas, High marginalization

Resumen

El alto consumo de los recursos naturales no renovables ha producido un aumento exponencial de gases de efecto invernadero que están provocando el calentamiento global por lo que todos los países del orbe presentan problemas ambientales, debido a la excesiva utilización de los combustibles fósiles, existen diferentes fuentes de generación causadas principalmente por los seres humanos, sin embargo no hay interés por su mitigación. Actualmente el interés mundial es contenerlos mediante la reducción del metano (CH_4) y del dióxido de carbono (CO_2). En el Acuerdo de París los países que lo integran se han comprometido a mantener la temperatura media mundial por debajo de 2 °C y limitar el aumento de la temperatura a 1,5 °C; en América Latina y principalmente ~~en~~ México, tiene el compromiso de disminuir 25% de los gases de efecto invernadero para 2030 y el 50% para 2050 (AZEL, 2018), para lograrlo es necesario contribuir con la aplicación de energías alternas más limpias. En el presente proyecto se propone utilizar los residuos orgánicos de los bovinos y porcinos para la producción de biogás y energía eléctrica en veintiséis municipios de más alta marginación del estado de Hidalgo que coadyuve a la disminución de la contaminación ambiental, el acceso a mejores servicios en beneficio de la calidad de vida de los habitantes y el minimizar el subsidio de energía eléctrica convencional.

Biocombustibles, Biogás, Alta marginación

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I. Introduction

Global warming is one of the challenges that the United Nations has as one of its main roles, as stated in the Paris Agreement, to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty (A.P., 2015), (UNFCCC, 2015). It is a priority to give the world a fighting chance to limit the global temperature increase to 1.5°C and avoid the worst effects of climate change (IEA, 2022), which undoubtedly requires a total transformation of the way energy is produced, transported and consumed.

According to the United Nations Environment Programme (UNEP, 2020) in 2019 for the third consecutive year, global Greenhouse Gas (GHG) emissions increased to an all-time high (UN, 2020) and stood at 52.4 $GtCO_2e$, without considering emissions from land-use change, and 59.1 GtCO2e if they are included.

GHGs are those gases present in the atmosphere that contribute to the greenhouse effect - the process by which thermal radiation emitted by the atmosphere is absorbed by the gases present and radiated in all directions - are of natural and anthropogenic origin - the result of human activity - Water vapour (H_2O), Carbon Dioxide (CO_2), Nitrous Oxide (N_2O), Methane (CH_4), Ozone (O_3), Sulphur Hexafluoride (SF_6), Hydrofluorocarbons (HFC's) and Perfluorocarbons (PFC's), (CEPSA, 2015), with CO_2 and CH_4 having the greatest impact due to the amount of tonnes discharged into the atmosphere.

Among the irreversible effects that are occurring are the increase in temperature, which is causing glaciers to melt at a faster rate, causing sea levels to rise, forests to dry up, fauna and flora to struggle to survive in ecosystems that are undergoing dizzying and complex changes that often have a serious and irreversible impact on biodiversity. According to information from the International Energy Agency in the dossier of the Spanish oil company CEPSA (2015), in the world the sectors that generate the greatest contribution of CO2 are: electricity generation (40.1% with 13Gt); industry (20.1%, 6.5Gt); transport (24.7%, 8Gt); building (7.7%, 2.5Gt); others (including agriculture and non-energy uses)* (7.4%, 2.4Gt).

The energy sector contributes two-thirds of GHG emissions and accounts for 90% of total industrial CO_2 emissions, and as a major emitter, holds the key to meeting the climate change challenge (IEA, 2021). Net zero means huge decreases in coal, oil and gas use, yet achieving net zero emissions by 2050 will require nothing less than the complete transformation of the global energy system (IEA, 2021).

Even so, according to data provided by the Renewables Global Status Report (REN21), in 2019 approximately 771 million people (10 % of the world's population) lack access to electricity (REN21, 2020). It is necessary to support countries with a deficit in access to this energy source, otherwise the world will still not ensure universal access to affordable, reliable, sustainable and modern energy by 2030 (World Health Organization (WHO), 2021). Another important factor is that changes in climate affect the energy sector, directly impacting fuel supply, energy production, physical resilience of energy infrastructure and energy demand (IEA, 2022), increasing frequency or intensity of extreme weather events such as heat waves, wildfires, cyclones, floods and cold snaps lead to disruptions in energy supply and difficulties in demand management (IEA, 2022).

The estimated share of renewables in global electricity production in 2018 was 73.8% non-renewable electricity; 26.2% renewable electricity; 15.8% hydropower; 5.5% wind power; 2.4% solar PV; 2.2% bioenergy; and 0.4% geothermal, CSP and ocean energy (REN21, 2019). In 2020 global per capita energy consumption was 71.5 GJ and in Mexico it was 50.2GJ, which meant a reduction of 5.5% globally with respect to 2019, in Mexico it was 15.9% mainly due to the COVID 19 - SARS2 pandemic that affected the entire planet (BP, 2021). Energy consumption through renewable energy is barely detectable in 2019 representing 0.30 ExaJ, in 2020 of 0.36 ExaJ in Mexico, globally it was 31.71 ExaJ, renewable energy generation was 39.2 TeraWatt-h, however it does not include biomass.

Mexico is expanding its solar PV capacity by 1.5 GW, despite difficult economic conditions, thanks in large part to abundant solar resources, falling prices and favourable policies in some countries (REN21, 2020), biomass energy use is still very low.

Due to energy marginalisation by communication routes to reach rural communities, the distance to rural communities is an important factor that makes access to natural gas and electricity more difficult. The way to reduce this gap is to use energy from the sun and organic waste (Barragan, 2018) to produce the biofuels (gas and electricity) needed to improve the quality of life of the most disadvantaged people, biomass can contribute significantly to sustainable development in both developed and developing countries, provided that the aspects related to its exploitation are carefully considered.

Bioenergy is a type of renewable energy from biomass (Sidartha et al., 2020) is defined as the biodegradable fraction of products, wastes and residues of biological origin is a source of solar energy stored by plants through the process of photosynthesis where carbon dioxide and water vapour are captured and converted into glucose with the help of sunlight, whose origin is starches, cellulose and lignin among others (Rincón et al, 2014), from agricultural activities - including substances of plant and animal origin - forestry, related industries, fisheries, aquaculture, and the biodegradable fraction of industrial and municipal waste.

The economic reuse of methane can contribute to the reduction of greenhouse gas emissions (García et al, 2016), (Ortiz, 2017) and contribute to reducing its consumption and the depletion of fossil fuel reserves, bringing with it the adoption of technologies in line with the possibilities of producers for the use of waste (Rivas et al, 2012) (Ortiz, 2017), in the generation of environmentally friendly clean energy. Organic solid waste - animal waste - can contribute to the reduction of the negative impact of methane and carbon dioxide.

Traditional biomass is mainly used for cooking and heating in rural areas of developing countries, accounting for approximately 8.5% of total final energy (Rincón et al, 2014). However it accounts for more than 10% of the world's primary energy supply and is the world's fourth largest source of energy (after oil, coal and natural gas) (Rincón et al, 2014), (SENER, 2012). In this sense, the global demand for biomass for energy purposes is estimated at 53 EJ (1,265 Mton eq oil) (Rincón et al, 2014), (Dávalos, 2012).

1.1 Impact of climate change on energy generation

Mexico is part of the Latin American region that contributes a large amount of natural resources to the world, particularly for its biodiversity; recognised since 2010 in the United Nations Development Programme, the United Nations Environment Programme, the Economic Commission for Latin America and the United Nations Conference on Trade and Development and the Environmental Conservation Monitoring Centre (UNDP, UNEP, ECLAC & UNCTAD, UNEP-WCMC, 2016) and UNEP in 2019 have suggested the desirability of its participation in programmes of environmental services derived from its ecosystems.

It should be noted that the systematic exploitation of natural resources over the centuries has contributed to the alteration of ecosystems, with negative results on the components of the environment; such as the variability detected in temperature, with effects on climate and bringing about climate change (CC); reflected in variations in hydrological cycles, in climatic seasons and in the increase and/or intensity of meteorological events. At the same time, the effect of all this brings changes in land quality, droughts, floods, loss of heritage, loss of human lives, which together increase poverty, especially among the rural population and/or those living in the countryside (ECLAC-European Union, 2017) and raise costs in both the production and sale of agricultural products. All of the above encourages further migration (Stein, 2018) to cities or other countries, abandoning agricultural production (Ortega-Marín et al, 2020).

In this order of ideas, maintaining natural resources entails a double responsibility: on the one hand, caring for biodiversity and, on the other, guaranteeing the availability of food for the 126 million Mexicans (National Institute of Statistics and Geography (INEGI), 2021). Currently, among the effects of the pandemic, food production is going through economic challenges in terms of income, and an increase in the population in situations of vulnerability and poverty is expected (Ortega Marín et al., 2020), which is why guaranteeing and making basic services available is a task that cannot be postponed.

In numerical terms, according to the National Evaluation Council (CONEVAL, 2021) between 2018 and 2020 the number of poor people increased from 51.9 to 55.7 million people. The population living in extreme poverty also increased from 8.7 to 10.8 million people. In terms of social deprivation, the lack of access to health services increased by 12.0 percentage points, from 16.2 per cent to 28.2 per cent.

On the other hand, to address CC in Mexico since 2013, a variety of research, public policies, programmes, models, among others, have been developed to understand, address and/or prevent climate change and vulnerability (Estrategia Nacional de Cambio Climático ENCC; 2013, National Institute of Ecology and Climate Change (INECC)-Government of Mexico 2022, National Institute of Ecology and Climate Change (INECC)-Global Environment Facility (GEF)-United Nations Development Programme (UNDP) and the Ministry of Environment and Natural Resources (SEMARNAT) 2012).

In terms of public policy, since 2001 the country has been part of ParlAméricas (2010), a Latin American initiative of countries that participate in the chambers of deputies, senators, legislative assemblies and/or parliamentary institutions of the Americas and the Caribbean, with the objective of improving and strengthening national and hemispheric democratic processes, through forums on key issues of common concern such as poverty and inequality (2006). In 2009 Altieri and Nichols published a proposal for attention to peasant agriculture with strategies and adaptive measures to protect and restore land properties in the face of events that affect them. In 2010, the ParlAmericas agendas included the new challenges for the Americas in the 21st century on climate change, foreseeing disaster and emergency preparedness and response, among other fundamental issues, particularly vulnerability, including Mexico (INECC, 2019).

The meeting included the topics of Disaster management in Latin America and the Caribbean (LAC): How to engage policy makers (Jeremy Collymore - WG1), Challenges for disaster preparedness, mitigation and response (Ricardo Mena - WG1) and Old and new threats to the security of Latin America (Gerardo Rodríguez Sánchez Lara - WG2) where ECLAC (2018) has been documenting in its publication Social Panorama of Latin America.

In 2015, at COP 21 in Paris, the countries of the Americas and the Caribbean presented their national contributions to the United Nations Framework Convention on Climate Change (ParlAmericas, Summary of Contributions, 2015).

Since 2016, the CC Meeting has been held annually, exchanging knowledge among its members, experts and interested civil society, orienting its practices towards mitigation and adaptation through workshops, exchange of dialogues, the creation of specialised resources and, as of 2019, ParlAmericas is an observer of the Intergovernmental Panel on Climate Change (IPCC). On the other hand, ECLAC (2017) is the international body under the United Nations that has been responsible for promoting discussions on CC:

- The main public policy challenges and challenges arising for LAC countries.
- The linkages that exist between the challenges presented and how this contributes to advancing the development agenda.
- The options for mitigation and adaptation measures and policies to address them.
- The key sectors and activities affected and where opportunities for policy decisions are identified.

It is also responsible for promoting the evaluation and prioritisation of CC mitigation and adaptation policies within the framework of EUROCLIMA and monitoring nationally determined contributions (NDCs) within the framework of the ECLAC-BMZ/giz Programme.

The Economics of Climate Change Unit of the Sustainable Development and Human Settlements Division of the same ECLAC (2017.1), in the framework of the actions contemplated by the EUROCLIMA Programme and which it operates, has published 12 documents in which it shares public policy recommendations related to issues of agriculture; water, biodiversity and forests; economics of climate change; energy and gasoline; development styles; climate change mitigation and adaptation measures; environmental fiscal policy; and social policy and climate change.

UNEP (2019) operates in LAC the public policies they issue, through programmes and projects on issues such as: Regional Platform for Innovation and Technology Transfer for Climate Change (REGATTA), Microfinance for Ecosystem-based Adaptation to Climate Change (MEbA), Ecosystem-based Adaptation (EbA) Mountain Programme, Euroclimate, United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) and Joint Programmes. As can be read, CC represents a major challenge for LAC and Mexico, and taking up all available information to understand both the issue and the way in which it has been addressed over time and what should have been done from the beginning and was left at least three decades ago (Arellano, 2014), leads to the determination that the decisions currently being taken should be the closest to compensating for the late attention to the various problems caused by the abuse of natural resources in countries like Mexico, with its great natural and irreplaceable wealth.

1.2 Problem statement

Inserted in the globally defined capitalist mode of production, the reality of Latin American countries and Mexico, over the centuries, has been that they have only been providers. They survive through inequality in access to food, housing, education, employment - to mention the most representative ones - in an environment of extreme poverty and vulnerability (Stein, 2018). This has been "addressed" by the UNDP and the UNEP promoted by the United Nations (UN) and the governments of each country, promoted - over time - in the Millennium Development Goals (ECLAC-UN 2010) and now in the Sustainable Development Goals (SDGs) 2030 (UNEP, 2021).

Among the actions developed to reduce GHGs, Mexico has participated in initiatives such as clean development mechanisms, payment for environmental services and the purchase of carbon credits. Particularly, the construction of biodigesters was an alternative that caused great interest at the beginning but unfortunately stopped being promoted and of the 720 biodigesters that were installed nationally (2005-2012), according to data from the Current situation and scenarios for the development of biogas in Mexico, 2024-2030. And one hundred between 2012-2018.

When designing the scenarios -according to the aforementioned publication-, it was concluded that the sectors with possibilities for profitable and productive application of biodigestion are large integrated livestock companies, corn flour plants (for vehicle methane), tequila plants (to generate steam) and PTAR (for self-consumption electricity). MSW treatment or dedicated crop processing are not yet validated.

However, generating biogas to access light or heat energy and biofertilisers, where several families benefit, in particular those considered to be highly and very highly marginalised. This is a feasible possibility and is what we intend to determine in this research, supported by biomass, manure and human waste generated in rural areas, and to achieve access to services for those who lack them, stop using fossil resources and join in caring for the environment, through the management of renewable energies and the application of viable adaptive measures (González Rosas et al, 2021).

1.3 Biomass as an energy source

Renewable energies, solar (thermal and photovoltaic), wind, hydro, biofuels and others, are in the transition towards a less carbon-intensive and more sustainable energy system (IEA, 2021).

The use of renewable energies is a way to mitigate the negative effects of environmental pollution. One of these types of energies is biomass, which through photosynthesis consumes carbon dioxide (CO2) and underproduces oxygen (O2) during the day and at night the opposite happens, capturing oxygen and releasing carbon dioxide.

The gas exchange that occurs during photosynthesis is essential for ecosystems and for life in general. Bioenergy accounts for about one tenth of the world's total primary energy supply. Currently (IEA, 2022), bioenergy accounted for approximately 11.6 %, or 44 exajoules (EJ), of total final energy consumption in 2019, more than half of this total bioenergy came from traditional biomass use, which provided about 24.6 EJ of energy for cooking and heating in developing and emerging economies (REN21, 2020).

According to the IEA (2022) modern bioenergy is a major source of renewable energy, its contribution to final energy demand in all sectors is five times greater than wind and solar PV combined, even when traditional biomass use is excluded, while the use of biomass in energy production offers emissions reductions in a wide range of areas, including low-emission fuels for aircraft, ships and other forms of transport, and the substitution of natural gas by biomethane to provide heat and electricity, access to clean energy for cooking has made less progress in recent years.

Large numbers of people in the developing world have no choice but to cook using traditional biomass systems, such as indoor open fires or inefficient cookers, resulting in high levels of household air pollution with severe health impacts that fall disproportionately on women (REN21, 2020). Globally 2.6 billion people still rely on polluting fuels. An estimated 125 million people use biogas for cooking worldwide, a figure that has remained almost constant over the last decade (REN21, 2020). Sustainable bioenergy is therefore also essential to bring clean cooking solutions to the 2.6 billion people who currently lack them (WHO, 2021).

1.4 The context in Mexico

Mexico, due to its geographical location, has a great potential for solar irradiation that favours the development of renewable energies through solar, wind, geothermal and biomass resources, according to data from the International Renewable Energy Agency (IRENA, 2019), which is an inexhaustible resource as long as it is managed in a sustainable manner, it is an inexhaustible resource as long as it is managed in a sustainable manner; endogenously and due to its territorial availability (Jeloal, 2022), waste treatment, but above all its use to provide clean cooking, which is still the biggest challenge at the moment. Mexico is located between 15° and 35° latitude, a region considered the most favoured in terms of solar resources, receiving, on average, 5.5 kWh/m^2 per day. Figure 1 shows the horizontal solar radiation reaching the country.

Figure 1 Solar resource. Global horizontal irradiation of Mexico average 1999-2018.
Source: Image captured from Solargis 2017 and World Bank Group, https://olc.worldbank.org/content/global-solar-atlas

Mexico has 5.5 times more territory than Germany, 5.0 times more radiation and 44.2 times more solar energy generated. Compared to China, Mexico has a territory 4.9 times smaller and an average solar radiation 1.2 times higher, however, the solar energy generated is equivalent to 0.1% of China's (Limón, 2021). Despite having ideal geographic and climatological conditions for the development of solar energy, and despite some successful efforts, Mexico continues to lag behind worldwide, which is why it is important to use biomass waste available through a complex and degradative biodigestion system in which part of the organic materials (carbohydrates, proteins and lipids) of a substrate (animal and vegetable waste) are converted into biogas and biofertiliser (González, 2014).

In Mexico, two types of bioenergy are used: biomass and biogas for electricity generation, mainly using sugarcane sap, but organic matter from agricultural, livestock, forestry, aquaculture, algaculture, fishing waste and other activities can also be used (SENER, 2016). Mexico has a high potential of biomass resources to be used as waste from agriculture, livestock and agro-industry, according to the Energy Balance of 2019 indicates that the production of biogas was 2.8 PJ and biomass was 361.17 PJ.

1.5 The context in the state of Hidalgo

The state of Hidalgo is one of the main energy suppliers in the central region of the country, whose geographical location places it among the primary energy exploitation sites oriented towards the high energy consumption region of Mexico. In the energy transformation process, the state plays a key role in the economic functioning of the region (PIAEE, 2018). In the State Development Plan 2016-2022 for the state of Hidalgo, in its Axis 2. "Hidalgo Prosperous and Dynamic", it proposes to generate economic growth locally, in balance with social development and the environment.

In Axis 5. "Hidalgo with Sustainable Development", it foresees providing energy to the population of Hidalgo under sustainable energy efficiency schemes and promoting the generation and consumption of electricity with sustainable sources, deciding to promote clean energy, accompanying the effort of the National Development Plan 2013-2018, with several Special and Sectoral Programmes (LOAEEH, 2018). It is located between the coordinates: Longitude 99°51'34.20" W 97°59'05.64" W, Latitude 19°35'52.08" N 21°23'54.60" N, its territory represents 1.1% of the national territory, with a population 3,082,841 inhabitants corresponding to 2.4 % of the country's total, 57 % is urban population and 43 % rural, representing at national level 79 and 21 % respectively, according to data from INEGI, 2020.

Considering the above described and taking into account the information that the Ministry of Welfare published by Decree of 30 November 2020, the Declaration of Priority Attention Zones for the year 2021 (DOF, 2020), of the 84 municipalities that make up the state of Hidalgo, 26 of them are in a situation of high and very high marginalisation, have economic limitations, communication routes and the cost of access to conventional energy sources is very high. However, these municipalities have sufficient solar radiation and biomass for their use and generation of clean biofuels. The objective of this project is to identify the energy potential of organic waste from cattle and pigs in the twenty-six highly marginalised municipalities of the state of Hidalgo to contribute to the generation of electricity for their inhabitants.

2. Materials and Methods

- Determine the amount of excreta that can be obtained through the amount of livestock existing in the state of Hidalgo.
- Calculate the biogas production based on organic waste by livestock type.
- Estimate the energy content of organic waste from its chemical content.
- Define the volume of biogas based on the amount of livestock produced in Hidalgo (26 high marginalisation municipalities).
- Calculate the use of biogas in high marginalisation municipalities.

The proposed techniques allow visualising the performance of the different excreta and the possible combination between them, in order to obtain maximum efficiency.

3. Results

When manure is used for agronomic purposes it can cause different impacts on soil and crop, depending on the management system, it is a valuable source of nitrogen (N), being able to fully or partially replace mineral fertilisation (Biau, 2012), (Osejos, et al, 2018). In natural decomposition processes, biomass releases methane (CH_4), methane is a gas with severe consequences for the greenhouse effect, having a global warming potential of up to 23 times greater than that of CO_2 (Martínez, 2015).

For this reason it is important to take advantage of it, considering the 26 High Marginalisation Municipalities and the information regarding livestock production in each of them reported in the SIAP to 2020, Table 1 presents the volume and variety of livestock available to use their excreta as a means to generate another form of environmentally friendly energy. Goats have not been considered in this study because only some of the municipalities have them, but cattle, sheep and pigs, as well as information for turkeys and poultry that is available in the study municipalities.

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No.	Municipality	Bovine Ton	Sheep Ton	Pigs Ton
1	Huehuetla	1332.20	8.01	99.86
2	Xochiatipan	180.66	3.66	95.18
3	Yahualica	267.51	1.94	69.18
4	Acaxochitlán	336.59	130.20	236.91
5	Agua Blanca de Iturbide	514.40	94.05	186.17
6	Atlapexco	567.78	5.96	148.92
7	Calnali	358.87	21.09	160.87
8	Chapantongo	809.68	97.94	288.74
9	Chapulhuacán	1177.09	11.07	137.28
10	Huautla	1237.94	6.08	209.29
11	Huazalingo	552.10	2.27	123.08
12	Jacala de Ledezma	373.65	30.89	127.95
13	Lolotla	616.42	7.85	121.94
14	Metztitlán	313.13	91.66	243.26
15	Mineral del Chico	131.71	221.76	27.02
16	La Misión	631.40	15.02	103.95
17	Nicolás Flores	207.41	21.37	83.92
18	San Felipe Orizatlán	2815.06	23.04	514.29
19	Pacula	325.52	20.32	128.48
20	Pisaflores	718.96	19.64	160.81
21	San Bartolo Tutotepec	1839.12	19.91	104.86
22	Tenango de Doria	793.20	16.60	177.81
23	Tepehuacán de Guerrero	634.25	19.72	191.19
24	Tianguistengo	458.92	13.63	84.93
25	Tlahuiltepa	559.16	35.26	91.08
26	Tlanchinol	1022.28	19.91	174.95

Table 1 Volume of livestock available in Highly Marginalised and Socially Backward Municipalities of the State of Hidalgo in 2020
Source: Own elaboration with information from SIAP http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php

Table 2 shows the production of excreta by type of animal, the biogas obtained needs to be converted from chemical energy to calorific energy, it has a high calorific value of 4700 to 5500 Kcal/m^3, which is equivalent to having a cubic metre of biogas and can be used in cooking food, for lighting homes, electric generators, water pumps among others (Villegas Aguilar, 2006), (Osejos, et al, 2018).

Assuming control of the variables of the biodigestion process, it could be considered that on average the energy content of this mixture is 20 MJ/m^3, which by changing units means 5.56 kWh/m^3, or similarly, each m^3 of biogas represents 0.0033 barrels of oil equivalent (BEP) or 305.8 m^3 of biogas has the energy content of a BEP (Martinez, 2015).

Type of animal	Size	Amount of excreta per day	Biogas yield	Biogas production (m3/y/day)	Relation
		(ETM) Kg/d	(m^3/Kg excreta)	(m^3/a/día)	Excrete : Water
Cattle	Large	15	0.04	0.6	1:1
	Medium	10	0.04	0.4	
	Small	8	0.04	0.32	
Pig	Large	2	0.07	0.14	1:1a 1:3
	Medium	1.5	0.07	0.1	
Poultry	Large	0.15	0.06	0.009	1:3
	Medium	0.1	0.06	0.006	
Sheep	Large	5	0.05	0.25	1:2a 2:3
	Medium	2	0.05	0.1	

Table 2 Excreta produced by type of animal
Source: Carlos Martínez Collado, 2007

According to the study conducted by Martínez Lozano in 2015, it indicates that pigs produce 4 kg of fresh manure per head per day; so each pig is capable of producing 0.33 m^3 of useful biogas per day (Osejos, et al, 2018); if it is considered to generate electricity.

Then additional aspects must be considered such as the type of biodigester to be used for chemical-thermal-mechanical-electrical conversion, which implies that for each cubic metre of biogas, 1.67 kWh of electricity can be obtained. This information and the information in Tables 1 and 2 were used to obtain the information in Table 3, concerning the biogas production generated from cattle, sheep, pigs, turkeys and poultry.

The volume in tonnes of each type of animal was converted to head of livestock to determine the volume of biogas and kWh of electricity available, for reasons of space only 10 of the 26 municipalities analysed are presented.

The study shows that in all municipalities sufficient energy is obtained to meet the energy demand that each household needs for cooking, lighting and the electricity required by each household.

No.	Municipality	Heads of livestock Prom	Biogas production m3/a/d	Consumption kWh/year per dwelling
1	Huehuetla	2664.40	1065.76	103.68
2	Xochiatipan	361.33	144.53	20.20
3	Yahualica	535.01	214.00	20.78
4	Acaxochitlán	673.18	269.27	15.72
5	Agua Blanca de Iturbide	1028.80	411.52	87.98
6	Atlapexco	1135.56	454.22	52.20
7	Calnali	717.74	287.09	36.95
8	Chapantongo	1619.36	647.74	101.58
9	Chapulhuacán	2354.18	941.67	91.75
10	Huautla	2475.88	990.35	108.95
11	Huazalingo	1104.21	441.68	88.71
12	Jacala de Ledezma	747.30	298.92	48.67
13	Lolotla	1232.84	493.14	115.48
14	Metztitlán	626.25	250.50	24.50
15	Mineral del Chico	263.42	105.37	25.36
16	La Misión	1262.79	505.12	105.12
17	Nicolás Flores	414.82	165.93	57.63
18	San Felipe Orizatlán	5630.12	2252.05	134.23
19	Pacula	651.04	260.42	111.01
20	Pisaflores	1437.92	575.17	71.87
21	San Bartolo Tutotepec	3678.24	1471.30	179.33
22	Tenango de Doria	1586.39	634.56	83.58
23	Tepehuacán de Guerrero	1268.50	507.40	41.29
24	Tianguistengo	917.84	367.14	55.59
25	Tlahuiltepa	1118.32	447.33	95.67
26	Tlanchinol	2044.56	817.82	52.20

Table 3 Biogas production by type of animal, kWh generation per day and kWh/year consumption per household in municipalities in the state of Hidalgo to 2021. *Source: Own elaboration with information from SIAP, of the volume of livestock production by municipality,* http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php.

Considering that the biogas demand for 4 inhab/d in a rural area is 24m^3/d (taking into account that it is required for: cooking= 2.1 m^3/d; lighting= 3.5 m^3/d; and electricity= 18.3 m^3/d), and that the electricity consumption of a household for 4 inhab/year is 2,956 kWh/year, it is observed that the production of kWh of electricity per municipality using cattle excreta is sufficient to meet the consumption demand required by each of the households in each municipality. Similarly, it was obtained that the energy demand per household in each municipality is satisfied with pigs and sheep; in the case of the amount of excreta from turkeys and poultry it is not sufficient separately, but the combination could give a favourable result, this is a second study to be carried out; as well as using excreta from dogs, cats and humans.

Regarding the adaptive measures of environmental care, it is possible to recover the actions learned over time for the care of their natural resources, considering ancestral practices, complementing them with the use of organic compost, a combination of planting nutrient-extracting vegetables that balance the properties of the soil and contribute to stop the deterioration of its layers, by building dams that contain it, to mention the most common in agriculture.

Conclusions

As has been observed, using bovine excreta provides the amount of energy needed to provide electricity, lighting and biogas in the households of the 26 Highly Marginalised Municipalities in the state of Hidalgo. Using the excreta obtained from sheep and pigs is also favourable for each household in the municipalities described above to have access to the minimum 24m^3/d of biogas required, or the 2,956 kWh/year that 4 inhabitants need for electricity. A second study is considering the use of excreta from poultry, turkeys, dogs, cats and people that each household owns, increasing the options for more biofuel and electricity available, so that all available organic waste can be used.

However, depending on the type and size of the biodigester to be used, the quantity and quality of the biol obtained can be used as organic fertiliser to help improve the quality of farmland in the municipalities under study. The energy obtained from a process of using biomass of animal origin can be considered "clean", if we also consider the low cost of its implementation compared to obtaining a barrel of oil equivalent, then it is a perfectly viable alternative.

The main component of this biofuel is methane, which is slightly lighter than air and has an average ignition temperature of 700°C, the flame reaches around 850°C, it can have an energy content of 20 to 25 MJ/m^3, while natural gas has an energy content of around 38 MJ/m^3; this is due to the CO_2 content and traces of hydrogen sulphide, hydrogen and nitrogen. However, in Mexico, producing 1 kWh of electricity with the primary energies currently used generates 0.675 kg of CO_2. So for every kWh generated with biogas, there is an equivalent saving in CO_2.

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