OPEN ACCESS

ORIGINAL ARTICLE

UNAH UNIVERSIDAD AGRARIA DE LA HABANA

Revista Ciencias Técnicas Agropecuarias 34
January-December 2025
ISSN 1010-2760, eISSN 2071-0054
Cu-ID: https://cu-id.com/2177/v34e19

Proposal for the Establishment of Appropriate Anaerobic Biodigestion Technology at the Robeba Farm

Propuesta para el establecimiento de la tecnología de biodigestión anaerobia adecuada en la Finca Robeba

Darielis Vizcay-Villafranca*, Yanoy Morejón-Mesa,
Geisy Hernández-Cuello and Yordan Oscar Amoros-Capdesuñer

Universidad Agraria de La Habana, Facultad de Ciencias Técnicas, San José de las Lajas, Mayabeque, Cuba. E-mail: ymorejon83@gmail.com, o ymm@unah.edu.cu, geisyh@unah.edu.cu, yordanoscar@unah.edu.cu

*Author for correspondence: Darielis Vizcay-Villafranca, e-mail: darielisv@unah.edu.cu o darielisvizcayvillafranca@gmail.com

ABSTRACT: The present research was developed on the "Robeba" farm; its objective was to establish the appropriate anaerobic biodigestion technology to be introduced into the farm, transforming waste into biogas and biofertilizer. To do this, the animal species existing in the scenario (cows and pigs) are determined, since these species will contribute the organic waste to the biodigester; Considering the herd movement, the number of animals is determined, which would make it possible to determine the biomass generated daily with the purpose of establishing the sizing of the appropriate biodigester technology and knowing the behavior of the economic and energy parameters. Among the most notable results, it was observed that the implementation of a tubular polyethylene biodigester is more viable compared to the installation of a fixed dome biodigester, representing an economic saving of 19,796 pesos due to technology selection; The necessary volume of this technology must be 20 m3, making it possible to produce 201.3 kg/day of biofertilizers, which represent a daily economic contribution of 2,516 pesos/day (100.65 USD/day), constituting added value, in addition to the energy and economic benefits to be obtained. On the other hand, with the installation of the selected anaerobic biodigestion technology, electrical energy can be produced for the home and the lights, which requires obtaining a 1 kW biogas generator.
Keywords: Installation, Anaerobic Digestion, biomass, economic savings.

RESUMEN: La presente investigación se desarrolló en la finca "Robeba", el objetivo de la misma consistió en establecer la tecnología de biodigestión anaerobia adecuada a introducir en la finca, transformando los desechos en biogás y biofertilizante. Para ello se determinan las especies animales existentes en el escenario (vacas y cerdos), pues estas especies aportarán los residuos orgánicos hacia el biodigestor; considerándose el movimiento de rebaño, se determina la cantidad de animales, lo cual posibilitaría determinar la biomasa generada diariamente con el propósito de establecer el dimensionamiento de la tecnología de biodigestor adecuada y conocer el comportamiento de los parámetros económicos y energéticos. Entre los resultados mas destacados, se observó que la implementación de un biodigestor tubular de polietileno es más viable en comparación con la instalación de un biodigestor de cúpula fija, representando un ahorro económico de 19 796 peso por concepto de selección de la tecnología; el volumen necesario de esta tecnología debe ser de 20 m^3, siendo posible producir 201,3 kg/día de biofertilizantes, que representan un aporte económico diario de 2 516 peso/día (100,65 USD/día) constituyendo un valor agregado, además de los beneficios energéticos y económicos a obtener. Por otra parte, con la instalación de la tecnología de biodigestión anaerobia seleccionada se puede producir energía eléctrica para la vivienda y las luminarias., lo cual requiere de la obtención de un generador de biogás de 1 kW de potencia.
Palabras clave: instalación, digestión, biomasa, ahorro económico.

Received: 03/01/2025
Accepted: 20/06/2025
The authors of this work declare no conflict of interests.
Author contributions: Conceptualization: D. Vizcay Villafranca. Y. Morejón Mesa. G. Hernández Cuello. **Data curation:** D. Vizcay Villafranca. Y. Morejón Mesa. **Formal Analysis**: D. Vizcay Villafranca. G. Hernández Cuello; Y. Morejón Mesa. **Investigation**: D. Vizcay Villafranca. Y. Morejón Mesa. Y. Amoros Capdesuñer. **Methodology**: D. Vizcay Villafranca. Y. Morejón Mesa. **Supervision:** D. Vizcay Villafranca. Y. Morejón Mesa. G. Hernández Cuello. **Validation:** D. Vizcay Villafranca. Y. Morejón Mesa. Y. Amoros Capdesuñer. **Writing - original draft**: D. Vizcay Villafranca. Y. Morejón Mesa. Y. Amoros Capdesuñer. **Writing - review & editing:** D. Vizcay Villafranca. Y. Morejón Mesa; G. Hernández Cuello.
The mention of trademarks of specific equipment. instruments or materials is for identification purposes. there being no promotional commitment in relation to them. neither by the authors nor by the publisher.

INTRODUCTION

The constant growth of the world's population, along with economic and social development, are the main drivers of the increasing global energy demand. This is currently supported by fossil fuels, which impedes long-term sustainability (Bilandzija *et al.*, 2018; González *et al.*, 2020; León *et al.*, 2021). These fuels (e.g., coal, natural gas, and oil) remain the dominant energy source in the global economy. However, if their consumption continues at the current rate, resources will be depleted within several decades due to their limited supply (Asakereh *et al.*, 2017; Al-Shetwi, 2022). Furthermore, there are many negative consequences of fossil fuel use, such as the emission of greenhouse gases and other pollutants. To prevent the rapid increase in greenhouse gases, the key is energy efficiency and/or switching to renewable energy sources (Huang *et al.*, 2017). Global energy consumption has significantly increased pressure on fossil fuels, resulting in an increase in the effects of global warming and climate change. Consequently, the global ambient temperature is expected to increase by approximately 2°C by 2050 due to polluting emissions from non-renewable energy resources (Bastida *et al.*, 2019; Al-Shetwi, 2022).

Currently, renewable energy is a sustainable and technically viable option for energy production and contributes a significant portion of electricity production in several countries (Muñoz *et al.*, 2018; González *et al.*, 2020; León *et al.*, 2021). Renewable energy is a promising alternative to alleviate the environmental, economic, and energy complications associated with the ever-increasing energy demand to meet the development and growth needs of the human population. However, despite all efforts to efficiently implement and harness renewable energy sources, greater public trust, policies, legislation, economic incentives, and education are needed to promote the growth, development, and implementation of these technologies (Zuñiga y Valenzuela, 2020).

The Sustainable Development Agenda's 2030 objective is to guarantee access to affordable, reliable, sustainable, and modern energy for all. This objective emphasizes the need to substantially increase the percentage of renewable energy, improve energy efficiency, and promote investments in clean infrastructure and technologies, among other aspects aspects (Casimiro *et al.*, 2021).

In Cuba, electricity production depends largely on fossil fuels, making it a national priority to enhance environmental sustainability through a shift in the energy mix and the use of renewable energy sources. Therefore, it is a viable alternative for transforming the Cuban economy and reducing the pollution generated by electricity production from fossil fuels (Lorenzo, 2017).

Currently, there is no proposal for the comprehensive use of renewable energy sources to replace conventional sources used on small farms dedicated to agricultural production. This is the case of the Robeba farm, which is why a feasibility study was conducted to implement a suitable anaerobic biodigestion technology on the farm.

MATERIALS AND METHODS

The Robeba farm, belonging to the Orlando Cuellar CCS, is located at 22°59′58.86″ North latitude and 82°08′11.75″ West longitude in the municipality of San José de Las Lajas, Mayabeque province. The total area is 47 ha, with typical Red Ferralitic soil throughout (Hernández et al., 2015). It has a flat terrain and an altitude of 80 m above sea level.

Meteorological variables recorded at the Tapaste Meteorological Station, San José de las Lajas, during the period January-September 2023, showed that the maximum temperatures reached in the region exceeded 32°C between June and September, and the coldest temperatures dropped on average to 21.1°C in January. Precipitation increased starting in June, with the highest average values in May and August, with 72 and 77 mm, respectively. Relative humidity ranged from 47% (minimum in March) to 84% (maximum in September), while wind speed reached a maximum of 3.6 km/h (2.2 mph) during August. The behavior of these climatic variables allows for the satisfactory development of agricultural production.

The farm has 10 milking cows, which remain housed 25% of the day. These achieved an average daily milk production of 6.9 L/cow in 2023, giving this farm a daily production potential of 69 L/day.

They also have 100 fattening pigs housed around the clock. These pigs remain housed for only three months and are then sold under an agreement with the state, at a price of 180 pesos/lb. Herd movement in the study scenario is reflected in Table 1.

Table 1. Herd movement on the Robeba farm

Herd Movement	Initial Stock	Final Stock	Animals/day	Average Mass, kg
Cows	10	10	10	400
Pigs	100	100	100	45

As a result of the study, electrical energy consumption at the Robeba farm during 2022 was analyzed, revealing an average monthly consumption equivalent to 3,767 kW.

The existing equipment and resources in the scenario under study, as well as their operating time, make it possible to determine the energy consumption per operation, as well as the percentage representation of each energy source. These results are reflected in Table 2.

This farm consumes 125.58 kWh of electricity daily, demonstrating the consumption of this production scenario. It is worth noting that water pumping alone accounts for 51.57% of the daily energy consumed.

To establish specific methodologies for sizing the different anaerobic biodigestion systems, the principles proposed by Morejón *et al.* (2022) are considered.

Methodology for the sizing and installation of anaerobic biodigesters

To calculate the design parameters of an anaerobic biodigester, according to Guardado (2007) and Morejón *et al.* (2022), it is necessary to know the input data and the data that must be determined (Table 3).

Table 2. Energy characteristics of the existing electrical equipment and resources at the Robeba farm

Electrical media and equipment	Power, kW	Quantity	Operating time, h	Energy consumed per day, kWh/day	Percentage, %
Water pump	18.5	1	3.5	64.75	51.57
Lighting	0.4	10	12.0	48.00	38.22
Household consumption	0.53	1	24.0	12.83	10.21
Total				125.58	

Table 3. Input and output data required for the design of an anaerobic biodigester

Parameters Input data	Unit
Daily biomass generated (Bmd)	kg dia^{-1}
Excrete-water ratio (N)	kg L^{-1}
Biogas yield (Y)	m^3 kg^{-1}
Hydraulic retention time (HRT)	día
Output data	
Daily volume of material (manure and water mixture) (Vdm)	kg dia^{-1}
Biodigester volume (Vbiodig)	m^3
Daily volume of biogas produced (G)	m^3 dia^{-1}
Biogas containment volume (V2)	m^3
Surge tank volume (Vtc)	m^3

The daily amount of material (DBM) is directly related to the amount of biomass generated, whether domestic, agricultural, or animal waste. In addition, the maximum yield and production increase plans must be taken into account.

The amount of daily biomass generated (Bmd) is determined through the following expression:

$$Bm_d = Ca \times Ce \times Rp \quad \times Rt, \quad kg. \quad dia^{-1} \tag{1}$$

where: Ca- Number of animals; Ce- Amount of excrement per animal, kg/day; Rp- Ratio of the average live weight of the animal population to the tabulated equivalent live weight; Rt- Fraction of housing time relative to day length, h/day

$$Bm_d = Ca \times Ce \times \left(\frac{PVp}{PVe}\right) \times \left(\frac{Te}{24h}\right), \quad kg\,.\,dia^{-1} \tag{2}$$

where: PVp = Average live weight of the animal population, kg; PVe = Tabulated equivalent live weight; Te = Hours per day the animal remains housed, h/day

The daily volume of material (a mixture of manure and water) (Vdm) is simply the sum of the residual and the dilution of the biomass (residual and water).

$$\text{Vdm} = (1 + N)\cdot Bmd, \quad m^3.dia^{-1} \tag{3}$$

where: N: Excrement-to-water ratio, kg L^{-1}. It is important to know that the density of water is 1000 kg/m^3.

Meanwhile, the volume of the biodigester (Vbiodig) is calculated by taking into account the volume of material (manure and water mixture) Vdm entering the biodigester and the retention time TRH.

$$V_{biodig} = \text{Vdm}\cdot TRH, m^3 \tag{4}$$

The daily volume of biogas (G) produced is then calculated:

$$G = Y \times B_{md}, m^3. \quad dia^{-1} \tag{5}$$

where: Y - Biogas yield, m^3 kg^{-1}

Biogas yield (Y) is determined by the expression:

$$Y = \frac{X}{C_e}, m^3. \quad kg^{-1} \tag{6}$$

where: X - energy conversion coefficient of the excreta produced daily, or the daily biogas production based on the type of organic waste, m^3/day.

For all types of biodigesters, the volume of the compensation tank (Vtc) is equivalent to the volume of gas produced, or ranges from 25 to 30% of the biodigester volume.

In the specific case of the calculations for the sizing of a fixed-dome biodigester (characterized by its three parts: conical, cylindrical, and spherical cap, represented in Figure 1), the following are presented.

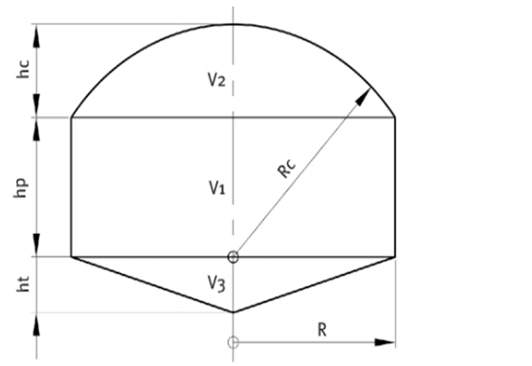


Figure 1. Main components of a fixed-dome biodigester. Source: Guardado (2007).

The steps to follow for its use are as follows:

The total volume of the biodigester (V_biodig) is calculated based on the volume of the water-manure mixture and the retention time, as shown in expression 4.

The radius of the predefined volume (R) is calculated

To calculate the radius of the predefined volume (R), the following expression is used:

$$R = \sqrt[3]{\frac{V_{biodig}}{(\pi \times 1.121)}} \quad (7)$$

where: R - Basic radius, m

Given the predefined radius of the volume (R), the unit is determined in meters (U = R/4).

where: U - Proportional unit

This proportional unit allows the determination of the remaining denominations by replacing U in the following proportions:

$$Rc = 5 \times U \quad (8)$$

$$D = 8 \times U \quad (9)$$

$$hc = 2 \times U \quad (10)$$

$$hp = 3. \times U \quad (11)$$

$$ht = 0.15 \times D \quad (12)$$

where: Rc = Dome radius, m; D = Diameter, m; hc = Dome height, m; hp = Cylinder height, m; ht = Base cone height, m

After determining the main geometric parameters, the volumes corresponding to the base cone, cylinder, and spherical segment of the dome are determined:

$$V_1 = Volumencilindro = R^2 \times hp \times \pi \quad (13)$$

$$V_2 = Volumencúpula = \frac{\pi \times h_c{}^2}{3}(3R - h_c) \quad (14)$$

$$V_3 = Vcono = R^2 \times \pi \times \left(\frac{ht}{3}\right) \quad (15)$$

RESULTS AND DISCUSSION

Technical-Economic Assessment of the Introduction of a Biodigester under the Conditions of the Robeba Farm

To determine the appropriate biodigester technology to install under the conditions of the Robeba farm, part of the Orlando Cuellar CCS, the sizing and construction costs of the fixed-dome and tubular polyethylene biodigester technologies were taken into consideration. This analysis was used to determine which of the two technologies would be more feasible based on construction costs or market acquisition costs.

For the correct sizing of the fixed-dome biodigester, the following parameters must be determined:

- Daily biomass generated (Bmd);
- Daily volume of material (manure and water mixture) (Vdm);
- Biodigester volume (Vbiodig);
- Fermentation chamber volume (Vcf);
- Cylinder volume (V1);
- Biogas containment volume (V2);
- Base cone volume (V3);
- Volume of the surge tank (Vtc).

On the other hand, to determine the potential energy input to be obtained based on the number of animals available, the following parameters must be determined:

- Biogas productivity (Y);
- Daily biogas volume (G).

Before proceeding with the aforementioned determinations, the herd movement in the scenario under study must be known, as listed in Table 1.

The results obtained from each of these sizing parameters are represented in Table 4 and Figure 2. These values are obtained from the herd movement designed by Nivio Pérez, owner of the Robeba farm, during the 2022-2023 period, as represented in the previous table.

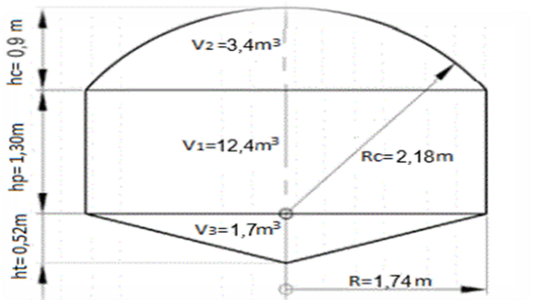


Figure 2. Main dimensions of the proposed fixed-dome biodigester.

Taking into account the foundations established by Morejón *et al.* (2022), that for every 350 kg of cattle, 10 kg of excreta are obtained, generating 0.36 m³ of biogas/day, with a 1:1-3 excreta-water ratio (using a 1:1 ratio) and with a recommended retention time of 40 days.

Table 4. Sizing of the fixed dome biodigester

Source of raw material	Animal / day	Average Mass, kg	Bm, kg/day	Vdm, m3/day	V_{biodig}, m³	V_1, m³	V_2, m³	V_3, m³	V_{cf}, m³	V_{tc}, m³
Cows	10	400	28.5	0.462	18.5	12.41	3.44	1.65	4.5	5.5
Pigs	100	45	202.5							

For pigs, it can be assumed that for every 50 kg, 2.25 kg of excreta are obtained, generating 0.10 m^3 of biogas/day, with a 1:1-3 excreta-water ratio (using a 1:1 ratio) and with a recommended retention time of 40 days. This allows determining the sizing of the tubular polyethylene biodigester for these species and numbers of animals.

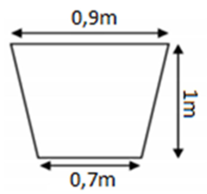
Based on the values obtained from the sizing of the fixed-dome biodigester, it is proposed that this biodigester have a volume of 20 m^3, to facilitate the installation process and the acquisition of the necessary materials. To determine the energy input, the amount of biomass generated daily, the biogas yield, and the daily biogas volume are considered (Table 5).

Table 5. Energy contribution of the animal population

Source of raw material	Animal / day	Average Mass,kg	Bmd, kg/día	Y, m^3/kg	G, m^3/día
Cows	10	400	28,5	0,080	18,5
Pigs	100	45	202,5		

To estimate the cost of the construction and installation of the fixed-dome biodigester system (excluding labor), Table 6 lists the materials required for the construction and installation of the technology.

In the case of the polyethylene tubular biodigester variant, the materials required for the construction and installation of the technology are listed in Table 7, to have an estimate of the cost of the construction and installation process (without considering labor), to have greater accuracy in the economic values, the main dimensions for a 20 m^3 biodigester were determined, these are reflected in Figure 3.



Roll Dimensions/Width (AR), m	2.0
a, m	0.7
b, m	0.9
p, m	1.0
Biodigester Length, m	14.5

Figure 3. Main dimensions of the trench and the proposed polyethylene tubular biodigester.

As can be seen in Tables 6 and 7, the cost of these technologies is not high, although there are differences between them. To better understand the aspects related to the sizing of both technologies, as well as the energy contribution to be obtained from the biogas produced by the introduction of these technological variants, Table 8 summarizes these design and energy values.

In the case of the fixed dome biodigester, considering the investment required for construction materials. which amounts to a cost of 34.871 pesos and if this is analyzed in terms of the energy savings to be obtained. for gasoline with a daily equivalent production of 14.8 L. from the price of this fuel which is equivalent to 25 pesos. daily savings of 370 pesos would be obtained. therefore in one year (considering 365 days) this saving would be equivalent to 135.050 pesos. which shows that in just three months of operation the investment in materials required for construction is recovered and a profit of 100.179 pesos is obtained in the remainder of the year. Similarly, if the same analysis is performed, but considering the electricity savings based on the potential generation to be obtained with the use of biogas,

Table 6. List of materials for the construction and installation of the proposed 20 m^3 fixed-dome biodigester to be installed and cost

Materials	UM	Quantity	Price**, weight/u	Cost, peso*
Cement	Bags	90	183	16 470
Sand	m^3	6	160	960
Gravel (38 mm)	m^3	7	200	1 400
15 cm Block	u	480	10	4 800
Solid Brick	u	650	8	5 200
3/8 Steel	kg	162	10	1 620
1/4 Steel	kg	24	12,5	300
Nails	kg	3	50	150
Wire for tying rebar	kg	5	25	125
Wood for formwork	m^3	0,3	120	36
Excavation	m^3	38	25	950
Backfill	m^3	18	20	360
Pipes for biogas collection and transportation	Accessories: Unions, elbows, PVC cleaner and glue, shut-off valves (quantity varies depending on distance from warehouses)		1 550	1 550
Pipes for manure supply	110 mm (4") pipes (2): 5 m/cubic meter		300	600
Total				**34 871**

*Peso: refers to the national currency (MN); the exchange rate is 25 MN = 1 USD.
** Construction material prices are established by the Ministry of Domestic Trade (MINCIN) in Cuba.

Table 7. List of costs for installing the polyethylene tubular biodigester

Materials	UM	Quantity	Precio unitario, peso/u	Costo, peso
Polyethylene module m^3 20 6,250 (per 10 m^3) 12,500	Polyethylene module m^3 20 6,250 (per 10 m^3) 12,500	Polyethylene module m^3 20 6,250 (per 10 m^3) 12,500	Polyethylene module m^3 20 6,250 (per 10 m^3) 12,500	Polyethylene module m^3 20 6,250 (per 10 m^3) 12,500
Excavation m^3 17 25,425	Excavation m^3 17 25,425	Excavation m^3 17 25,425	Excavation m^3 17 25,425	Excavation m^3 17 25,425
Pipes for biogas collection and transportation. Accessories: Unions, elbows, PVC cleaner and glue, shut-off valves (quantity varies depending on distance from buildings).	Pipes for biogas collection and transportation. Accessories: Unions, elbows, PVC cleaner and glue, shut-off valves (quantity varies depending on distance from buildings).		Pipes for biogas collection and transportation. Accessories: Unions, elbows, PVC cleaner and glue, shut-off valves (quantity varies depending on distance from buildings).	Pipes for biogas collection and transportation. Accessories: Unions, elbows, PVC cleaner and glue, shut-off valves (quantity varies depending on distance from buildings).
Total				**15 075**

Table 8. Sizing and energy contribution of the biogas to be obtained with the installation of biodigestion technology

Sizing parameters	Fixed Dome Biodigester	Tubular Polyethylene Biodigester
biodig, m^3	18.5	18.5
Vcf, m^3	4.5	-
Vtc, m^3	5.5	5.5
Vgas, m^3	5.5	5.5
Roll width (polyethylene), m	-	2.0
Roll length (polyethylene), m	-	14.5
Upper base of trench, m	-	0.9
Trench bottom base, m	-	0.7
Trench Height. m	-	1.0
Energy Parameters		
Y. m^3/kg 0.080	0.080	
G. m^3/day 18.5	18.5	
Potential Energy Savings		
Electricity. kWh 33.3	33.3	
Natural Gas. m^3 11.1	11.1	
Charcoal. kg 5.55	5.55	
Wood. kg 49.95	49.95	
Gasoline. L 14.8	14.8	
Fuel Alcohol. L 22.2	22.2	
Fuel Oil. L 12.95	12.95	
Biofertilizer Production kg/day 201.3	201.3	

which amounts to 14.86 kWh per day, and using the rate established by the Electric Company in Cuba:

- From 0 kWh to 100 kWh: 0.33;
- From 101 kWh to 150 kWh: 1.07;
- From 151 kWh to 200 kWh: 1.43;
- From 201 kWh to 250 kWh: 2.46;
- Over 250 kWh: 3.12 per kWh.

This would result in an average monthly savings of 890 pesos. which translates to an annual savings equivalent to 10.680 pesos. This demonstrates that the investment in the materials required for construction is recovered in just 3.4 years of operation. resulting in a profit of 16.6 years. considering that the useful life of a fixed-dome biodigester is 20 years. These elements demonstrate the economic feasibility of the proposal analyzed. For the tubular polyethylene biodigester. the investment required for construction materials amounts to a cost of 15.075 pesos. If this is analyzed in terms of the energy savings to be obtained. only for gasoline with a daily equivalent production of 6.60 L. based on the price of this fuel which is equivalent to 25 pesos. a daily saving of 165 pesos would be obtained. Therefore. in one year (considering 365 days) this saving would be equivalent to 60.225 pesos. This shows that in just three months of operation. the investment in materials required for construction is recovered and a profit of 45.150 pesos is obtained for the remainder of the year. This element demonstrates the economic feasibility of the proposal. Similarly. if the same analysis is performed. but considering the electricity savings based on the potential generation to be obtained with the use of biogas. which amounts to 33.3 kWh per day. and using the rate established by the Electric Company in Cuba:

- From 0 kWh to 100 kWh: 0.33;
- From 101 kWh to 150 kWh: 1.07;
- From 151 kWh to 200 kWh: 1.43
- From 201 kWh to 250 kWh: 2.46;
- Over 250 kWh: 3.12 per kWh.

This would result in an average monthly savings of 2.721 pesos. which represents an annual savings equivalent to 32.652 pesos. This shows that the investment in construction materials is recovered in just 1.1 years of operation. resulting in a profit of 3.9 years. considering that the useful life of a tubular polyethylene biodigester is 5 years. These elements demonstrate the economic feasibility of the analyzed proposal. It is worth noting that the proper sizing of this type of technology promotes maximum utilization of the waste obtained in production scenarios.

As evidenced in Table 8. the installation of biodigesters in agricultural production units constitutes an energetically viable option. to which must be added the contribution to environmental conservation and care. Therefore, to adopt biodigestion technology on the farm under study, the introduction of a tubular polyethylene biodigester is economically advisable. With the introduction of this technology, it would be possible to:

- Generate electricity to power the water pump. lighting. and the home. which requires a 20 kW biogas generator. considering all energy sources. If water pumping is excluded. a 1 kW biogas generator would be required. According to the Chinese company Shenzhen Teenwin Environment Co. the price of these biogas generators ranges from $550 to $1.250 (13.750 to $31.250 Mexican pesos).
- In addition. it is possible to obtain 201.3 kg/day of biofertilizers. representing an economic contribution of $2.516 pesos (100.65 USD). based on the international market price of biofertilizers. which reaches $500/t (12.500 pesos/t).

CONCLUSIONS

- To meet the farm's energy demand. the installation of a polyethylene tubular biodigester is suggested. given its low installation costs.
- With the installation of a 20 m^3 polyethylene tubular biodigester. it is possible to produce 201.3 kg/day of biofertilizers. representing a daily economic contribution of 2.516 peso (USD 100.65). which constitutes added value. in addition to the energy and economic benefits obtained.
- With the introduction of anaerobic biodigestion technology. it is possible to generate electricity to supply and operate lighting and household consumption. which requires the acquisition of a 1 kW biogas generator.

RECOMMENDATIONS

- Continue implementing the theoretical and methodological foundations used in the research in other production scenarios.

REFERENCES

AL-SHETWI, A.Q.: "Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges", *Science of The Total Environment*, 822: 153-645, 2022, ISSN: 0048-9697.

ASAKEREH, A.; SOLEYMANI, M.; SHEIKHDAVOODI, M.J.: "A GIS-based Fuzzy-AHP method for the evaluation of solar farms locations: Case study in Khuzestan province, Iran", *Solar Energy*, 155: 342-353, 2017, ISSN: 0038-092X.

BASTIDA, L.; COHEN, J.J.; KOLLMANN, A.; MOYA, A.; REICHL, J.: "Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming", *Renewable and Sustainable Energy Reviews*, 103: 455-462, 2019, ISSN: 1364-0321.

BILANDZIJA, N.; VOCA, N.; JELCIC, B.; JURISIC, V.; MATIN, A.; GRUBOR, M.; KRICKA, T.: "Evaluation of Croatian agricultural solid biomass energy potential", *Renewable and Sustainable Energy Reviews*, 93: 225-230, 2018, ISSN: 1364-0321.

CASIMIRO, R.L.; RAMÍREZ, H.G.; MARTÍN, M.G.: "Uso de las energías renovables en las fincas familiares, sus potencialidades y desafíos en la transición de la matriz energética local", *Eco Solar*, (78): 19-27, 2021, ISSN: 1028-6004.

GONZÁLEZ, L.Z.; TORRES, G.A.P.; GONZÁLEZ, A.V.: "Educación en energías renovables desde el enfoque CTS", *Libro de Actas*, 843, 2020.

HERNÁNDEZ, J.A.; PÉREZ, P.; BOSCH, I.D.; CASTRO, S.N.: *Clasificación de los suelos de Cuba. Instituto Nacional de Ciencias Agrícolas, San José de las Lajas, Cuba, 91 p*, Ed. Instituto Nacional de Ciencias Agrícolas, Instituto Nacional de Ciencias Agrícolas, ed., San José de las Lajas, Mayabeque, Cuba, 91 p., 2015, ISBN: 959-7023-77-6.

HUANG, A.W.K.; CHEN, W.; ANANDARAJAH, G.: "The role of technology diffusion in a decarbonizing world to limit global warming to well below 2 C: An assessment with application of Global TIMES model", *Applied energy*, 208: 291-301, 2017, ISSN: 0306-2619.

LEÓN, M.J.A.; MOREJÓN, M.Y.; MELCHOR, O.G.C.; ROSABAL, P.L.M.; QUINTANA, A.R.; HERNÁNDEZ, C.G.: "Dimensionamiento de un parque solar fotovoltaico para el Centro de Mecanización Agropecuaria (CEMA)", *Revista Ciencias Técnicas Agropecuarias*, 30(4), 2021, ISSN: 2071-0054.

LORENZO, A.J.A.: "Cálculo de instalación. Manual para instalaciones fotovoltaicas autónomas", *Era solar: Energías renovables*, (197): 6-15, 2017, ISSN: 0212-4157.

MOREJÓN, M.; TORRICO, A.; MORENO, M.V.; ABRIL, H.D.A.: *Fundamentos para la introducción de las fuentes de energía renovables en sistemas agropecuarios. Caso de estudio: Introducción de biodigestores en fincas pertenecientes al departamento Cundinamarca, Colombia*, Ed. CienciAgro., Cundinamarca, Colombia, Depósito Legal: 4-1- 4299-2022. Publicado en: La Paz-Bolivia, por el Instituto Agrario Bolivia, con el sello editorial CienciAgro., 2022, ISBN: 978-9917-9928-0-6.

MOREJÓN, M.Y.; HERNÁNDEZ, C.G.; VIZCAY, V.D.; AMOROS, C.Y.O.: "Determination of Appropriate Anaerobia the Technology of Biodigestion for a System of Poultry Production", *Revista Ciencias Técnicas Agropecuarias*, 33(4): cu-id, 2024, ISSN: 2071-0054.

MUÑOZ, A.Y.; RUBIO, G.A.; MENTADO, D.C.I.: "Los incentivos económico-financieros por el empleo de las fuentes renovables de energía. Marco jurídico en Cuba y Ecuador", *Revista Universidad y Sociedad*, 10(2): 53-60, 2018, ISSN: 2218-3620.

ZUÑIGA, L.Y.; VALENZUELA, G.A.: "Educación en energías renovables desde el enfoque CTS", *Pensamiento y Acción*, 28: 47-59, 2020.