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Economic Analysis of Biogas Production via Biogas Digester Made from Composite Material

KeChrist Obileke [1,*], Golden Makaka [1], Nwabunwanne Nwokolo [1], Edson L. Meyer [2] and Patrick Mukumba [1]

1 Department of Physics, University of Fort Hare, Private Bag X1314, Alice 5700, South Africa
2 Fort Hare Institute of Technology, University of Fort Hare, Private Bag X1314, Alice 5700, South Africa
* Correspondence: kobileke@ufh.ac.za

Abstract: This study seeks to evaluate the economic implication of a biogas digester built from composite material to ascertain its cost effectiveness. The feasibility study conducted indicates that a brick made only of fixed dome digester costs between USD 3193.99 and USD 4471.59. This high cost is attributed to the construction material, thus prompting the need to use materials of lower cost for affordability and sustainability. Hence, the digester under study was made from composite material comprising high-density polyethylene (HDPE), bricks and cement. The inlet and outlet chambers were built using bricks and cement, while the digestion chamber was made from HDPE material. From the economic analysis conducted, the total initial investment cost of the biogas digester was reported to be USD 1623.41 with an internal rate of return (IRR) of 8.5%, discount payback period (DPP) of 2 years and net present value (NPV) of USD 1783.10. The findings equally revealed that the estimated quantity of biogas could replace 33.2% of liquefied petroleum gas (LPG) cooking gas. Moreover, the biogas daily yield of 1.57 m^3 generates approximately 9.42 kWh of electricity, which costs about USD 1.54. Thus, the study recommends the use of composite material of plastics and bricks in constructing the biogas digester, as it is cost effective and sustainable.

Keywords: composite materials; biogas; biogas digester; economic analysis; economic indicator

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1. Introduction

Anaerobic digestion of waste is contributing significantly to solving energy, environmental and agricultural-related problems. This has encouraged the development of biogas technology globally as well as the need to study its economic viability [1]. Given the limited supply of fossil fuels and their negative impact to the environment, studies have been completed to find out environmentally friendly and renewable alternative fuels [2]. Bhatt and Tao [3] mentioned that current and future research in renewable energy has contributed to the rapid increase in investment and implementation of clean energy technologies around the world. To this development, the conversion of waste to energy through anaerobic digestion is a promising option. Moreover, the growing global concerns on sustainable waste management bring AD technology to light. It can promote sustainability and meet the world's renewable energy needs. In this regard, energy economist, industries and agencies are seeking low-cost technologies such as biogas digesters for the generation of energy. Several studies have looked at the economic feasibility of the biogas digester and its gas yield using different materials and substrates.

Kozlowski [1] economically evaluated the possibility of using dairy waste for the production of electricity and heat. The study reported that the generated waste from the dairy could produce approximately 14.785 MWh electricity and 57.815 GJ of heat. This supports the construction of biogas plants that can generate electrical power of 1.72 MW. Ogrodowczyk [4] studied the economic analysis of a biogas digester at a sugar factory. In the economic part of the study, the following economic indicators were determined: net present value (NPV) of 14,089.57 PLN (USD 3,294,844.78), internal rate of return (IRR) of 12.48 PLN (USD 2.92) and discounted payback period (DPP) of 8 years. The initial cost of investment of the biogas digester was 2,446.000 PLN, which is equivalent to USD 572,283.28. From the economic perspective, the study affirms that the higher NPV indicates an economic benefit of the bio-digester. On the other hand, the calorific value of methane from biogas was reported to be 9.17 kWh/m^3. A total of 13,104 MWh/year of energy was generated as electricity, costing 16,358 PLN/MWh.

Tufaner and Avsar [5] studied the economic analysis of biogas production from an anaerobic digestion system for cattle manure. The study aimed at determining the economic viability of an anaerobic digester system, and it focused on the domestic production conditions. In this study, it was reported that the total investment cost (fixed cost) for the 3 m^3 underground bio-digester was 4433 TL (Turkish Iira), which is equivalent to USD 270.52. Looking at the economic perspective of the study, the liquefied petroleum gas (LPG) value of the biogas generated was 157 kg, and it had an annual biogas production of 365 m^3 and biogas annual turnover of 1210 TL (USD 683.66). Unfortunately, the study did not focus on the economic indicators and parameters. The findings revealed that the biogas equivalent of 4.4 LPG cooking gas of 12 kg per year can be produced from cow dung.

The techno-economic evaluation of biogas production from waste in a biogas digester was conducted by Al-Wahaibi [6]. The study aimed at assessing the economic feasibility because of the fluctuating value of biogas from food waste. Focusing on the economic analysis of the study, this revealed that cat USD 0.2944 m^3, breaking even occurred. Hence, any prices above this rate yield a positive net present value (NPV). The study reported the DPP and NPV of 6 years and USD 3108.00, respectively.

To analyze the economic performance of anaerobic digestion of a biogas digester in terms of its NPV and IRR concept, Gebrazgabher [7] conducted the study, using the green biogas plant in Netherlands as a case study. The total investment cost of the bio-digester was reported to be €675,000.00 (USD 7,245,990.00), with NPV and IRR as €400,000.00 (USD 4,293,600.00) and 21%, respectively. These economic indicators were necessary to measure the cost-effectiveness of the biogas digester. As seen in the previous studies, the study revealed a higher NPV value, which shows the greater economic benefit of the project. In the study, an electricity yield of 222.30 kWh ton^{-1} of feedstock was digested. However, electricity production of a total of 2 MW/year was obtained in the study.

A feasibility study on the anaerobic digestion of food waste was conducted by the National Institute of Renewable Energy [8]. This study focuses on assessing the feasibility of developing an anaerobic digestion tank for biogas production. According to the study, the cost of the biogas digester was USD 561.00 per ton, while the operation and maintenance costs and NPV were USD 77 to USD 140.00 and −6,762,992.00, respectively. The NPV results predicted that the project would lose money, despite reasonable food waste and locations that could support the biomass plant. This loss of money from the project can be due to the negative present value reported in the investigation. However, a biogas production rate of 15 ft 3 biogas/IbVS was produced, and the electricity cost was USD 0.078/kWh.

The previous studies mentioned above focus on the economic analysis of biogas digesters, assessing the energy content of the biogas yield and cost of electricity. During the literature review, the authors observed that the nature of the design in terms of type of the digester and materials as well as the design orientation (aboveground or underground) were not considered. This is necessary, as it also contribute to the feasibility of the project economically. The present study will fill this gap, thereby contributing to existing knowledge. Therefore, the aim of the study is to determine the economic feasibility of generating biogas in a biogas digester built from composite materials. The study will also address and calculate how much methane is required to replace the LPG gas used for cooking in the study site. The findings from this study will provide relevant information and serve as a guide to mostly energy economists and consultants regarding the level of economic feasibility to take up a biogas digester project. In this regard, it will provide energy savings and the amount of electricity required through financial and economic benefits. A holistic analysis of the variables and indicators or parameters that satisfy the feasibility of biogas digesters will also be presented. These will help to advise accordingly.

2. Materials and Methods

2.1. Materials

The Fort Hare Dairy Trust Production provided the organic waste (cow dung) used in the study. The inoculum used was taken from an existing working biogas digester located in one of the community engagement projects at Melani (Eastern Cape Province of South Africa). Thereafter, the collected inoculum was kept at room temperature of anaerobic condition.

2.2. Physiochemical Properties of the Substrate

The following parameters were examined and reported as follows: pH: 7.83 at 30 °C; total solids: 130,800 g/L; volatile solids: 110,467 g/L; chemical oxygen demand: 42,583 g/L [9].

2.3. The Economic Analysis

To evaluate the feasibility of installing a biogas digester, a preliminary economic study was conducted. The biogas digester was fed with cow dung collected from the Fort Hare Dairy trust farm. The produced biogas aimed to substitute the conventional LPG gas used for cooking in a residential building at the study site. This is to save cost. The reduction in cost through the economies of scale can be effective if the cow dung is processed at a higher plant scale. This is possible or obtainable through the collection and processing and development of a centralized animal waste (cow dung). For the sake of the economic evaluation, which is focus of our anaerobic digestion experiment, a scale of 9000 kg/month of cow dung was reported (Table 1).

Table 1. Calculation of estimated biogas production (per month).

Parameters Reported	Values
Amount of fresh cow dung (24% dry matter)	9000 kg/month
Amount of cow dung (dry matter)	6589.2 kg/month
Quantity of biogas produced	10,500 L/kg/month
Methane content present in the biogas	60%
Amount of methane produced	630 mL/g
Total amount of methane from the cow dung	4151.2 m^3/month

The economic parameters analyzed include total initial investment cost (fixed cost), total income, cost of maintenance, payback period, profitability, internal rate of return, cost annuity and cost of energy. The importance of these indicators or parameters is that it helps determine the extent of the feasibility in carrying out the biogas digester installation. According to Kabyanga [10], the financial assessment investment includes the following.

2.3.1. Net Present Value (NPV)

The net present value (NPV) is the sum of the present value of the money moved into and out of an investment project [11]. According to Ogrodowczyk [4], NPV determines the present rate of the total investment cost, considering the changes in the value of capital over time. For any project to be feasible or profitable, the NPV should be higher or equal to zero [4]. However, a discount rate of 3.6% was used for the project's study. Relating the NPV to the study, it focuses on the sum of the present value of all the cash inflow and outflow that is linked to the investment of the biogas digester project at time t = 0. This was calculated using Equation (1):

$$\text{NPV} = -I_0 + \sum_{t=0}^{T} (R_t - I_t) q^{-t} + L_T q^{-T} \tag{1}$$

Equation (1) can also be written as:

$$\text{NPV} = -I_0 = (R \times PF) + L_T \times q^{-T} \tag{2}$$

where I_0 is the cost of investment (USD) at the start of the project, T is the lifetime of the project in years, R or R_t is the annual returns/return in time period t, I_t is the investment in time period t, PF is known as the value factor present in years, L_T is the yield of liquidation or value of salvage and q^{-t} is the discount factor, which is calculated as

$$q-^{t} = \left(1 + \frac{i}{100}\right)^{-t} \tag{3}$$

2.3.2. Internal Rate of Return (IRR)

This is the obtainable interest tied up in a project of a particular investment. It computes at what interest the NPV will be zero. The internal rate of return can be expressed as

$$0 = -I_0 + \sum_{t=0}^{T} R_t \left(1 + \frac{IRR}{100}\right) + L_T \left(1 + \frac{IRR}{100}\right)^{-T} \tag{4}$$

Equation (3) can be written as

$$\text{IRR} = I_i - NPV \left(\frac{i_2 - i_2}{NPV_2 - NPV_1}\right) \tag{5}$$

2.3.3. Profitability or Return on Investment (ROI)

This measures the behavior of a project's average profit per time interval. This is calculated by dividing the net profit by the net worth. A high return on investment (ROI) favors the cost of the investment. The ROI is a parameter used to relate the profit and capital used in an investment. However, the profitability of ROI is expressed as:

$$\text{ROI} = \frac{Net\ profit}{Total\ investment} \times 100 \tag{6}$$

2.3.4. Annuity (A)

This is the fixed amount of money paid on an annual basis for an investment or project. Annuity can be either fixed or variable. The annuity is calculated as:

$$\text{A} = \text{NPV} \times \text{RF (i, T)} \tag{7}$$

where RF is the capital recovery factor, which is calculated as:

$$\text{RF} = \frac{q^t(q-1)}{q^t - 1} \tag{8}$$

In addition, i and T are the discount rate and period in years, respectively.

2.3.5. Cost Annuity (A_k)

The cost annuity denoted as A_k is the annual cost of a project [11]. The cost annuity is important, as it helps evaluate the favorability of an investment project based on cost per annum [12]. Cost annuity is calculated as

$$A_k = K_0 + (I_0 - L) \times R_F\ (i, t) + L \times I \quad (9)$$

where K_0 is the cost of operation per unit time (USD), I_0 is the cost of investment (USD), L is the liquidation time (years), R_F is the recovery periods (years), while i and t are the interest rate (%) based on assumption and project duration, respectively.

2.4. Cost Analysis Study

The study considered the employment of a fixed dome biogas digester design made from a high-density polyethylene (HDPE) and bricks/cement. Other materials such as Teflon, acrylonitrile butadiene styrene (ABS) and fiber-reinforced plastic can be used for the fabrication/construction of a digester chamber. However, the choice of HDPE in the present study was based on its durability as well as quick biogas production within a 3 to 4-day retention time [13], This is attributed to the nature or type of the material, which easily allows enhancement of the diversity of microbial communities (degradation of microbes), thereby increasing their synergistic activity and playing a vital role during acidogenic fermentation (one of the stages of anaerobic condition). During this process, it increases the total volatile fatty acid yield responsible for biogas production [14]. Another reason for the use of HDPE for the digester chamber was because of its characteristic to withstand the moisture exposure, corrosive gases and digestion of feedstock as well as prevent the emission of odor and gases (H_2S, CH_4, CO_2 and NH_4). In addition, it is a good insulator and can be warm, producing biogas at a lower temperature. HDPE possesses high corrosion resistance, high strength, no leakage, and good airtightness as well as fast and easy fabrication and installation [15]. Above all, it can withstand harsh environmental conditions and still maintain anaerobic conditions. This is different from other designs where bricks are used for the construction of the digester chamber. The use of bricks for the digester chamber results in defects such as cracks. Hence, this necessitated the use of an alternative material for fabrication/construction of the digester chamber, as shown in Figure 1.

Figure 1. Fabricated high-density polyethylene biogas digester.

In the study, brick/cements were used for the construction of an outlet and inlet chamber and not for the digester chamber because of the disadvantages mentioned earlier. In addition, HDPE was able to withstand the pressure within the entire biogas digester. This type of design is recommended for rural settings due to the ease of installation. The biogas digester chamber was built underground for thermal insulation, as shown in Figure 2. In so doing, the soil provides insulation for the system.

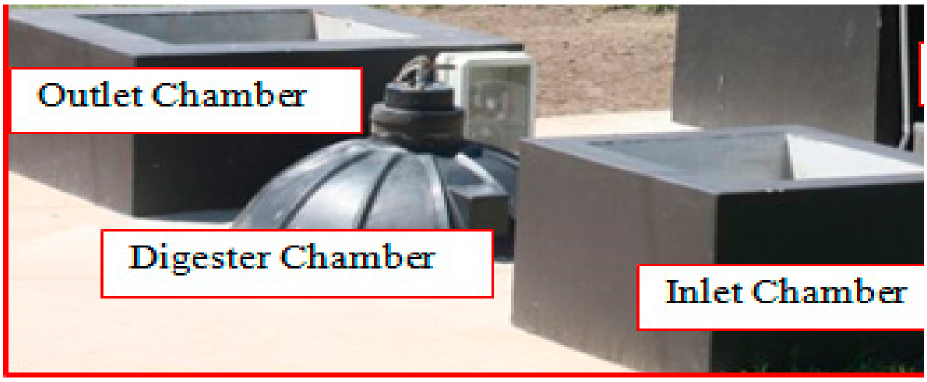

Figure 2. The biogas digester.

One major factor to be considered when choosing the volume of the biogas digester is the number of people that will benefit from the biogas when produced. According to Tufaner and Avsar [5], one person requires approximately 0.34–0.42 m^3 of biogas to cook a daily meal. Therefore, we assume that the quantity of biogas that a person would use for cooking daily is 0.5 m^3 day^{-1} on average and consider that a digester volume of 6 m^3 can produce 1 m^3 of biogas per day. The cost–benefit analysis was conducted on the biogas digester of 2.15 m^3 volume (small family size digester), which produced biogas of about 0.35 m^3 per day, as shown in Table 2. In terms of the animal dung, Tufaner and Avsar [5] assumed that a cow produced 10 kg of dung per day.

Table 2. Summary of cost analysis of the study.

Number of Cows Considered	Quantity of Cow Dung per Day (kg)	Volume of Biogas Digester (m^3)	Estimated Daily Cooking Demand (m^2/day)	Amount of Biogas per Day (m^3)	Amount of Electricity Generated (kWh)	Quantity of Cow Dung (kg/day)	Quantity of Water Added (L/day)
16	300	2.15	0.2	0.35	0.324	26	52

In the fabrication/construction of a biogas plant, the construction of cost items considered as fixed-cost items includes the following: a PVC pipe (110 mm thickness), concrete reinforcing mesh, concrete stone, all-purpose sand, UG rodding eye, and sealant. The variable costs considered include the labor costs, costs of fabrication of the digester chamber, and the cost of digging the pit. For the operating cost components, the maintenance and repair cost, water cost and labor cost were considered. The value of the biogas produced was calculated based on the equivalent price of a 5 kg cooking gas cylinder cost at approximately R 500.00–R 900.00 (USD 31.94–57.00) on average. However, the cost of cow dung, benefit of the fertilizer (digestate), and social and environmental benefit were not considered in the calculation.

Table 2 shows that the 300 kg of cow dung was produced from 16 cows, which was used to feed the 2.15 m^3 biogas digester. This generated 0.35 m^3 (0.324 kWh) of biogas per day for 0.2 m^2/day cooking demand daily for 5–8 households.

Therefore, the rate of cow dung required to be fed to the biogas digester daily can be calculated using the following:

$$m_s = \frac{E}{0.036} \times 0.1 \tag{10}$$

where E refers to electrical energy (kWh/day).

Calculations:

- Amount of methane produced (mL/g) = amount of biogas produced × methane content produced;
- Total amount of methane from the cow dung = amount of cow dung × amount of methane produced × $(10^3)/(10^6)$;
- LPG volume in one cylinder (L/cylinder) = Amount of LPG in a cylinder/Density of LPG;
- LPG volume in one cylinder (m^3/cylinder) = Volume of LPG (L/cylinder)/1000;
- Amount of gas after expansion = Volume of LPG (m^3/cylinder) × LPG expansion rate;
- Number of cylinders that can replaced by biogas per month = Total amount of methane based on the quantity of cow dung/amount of gas after expansion;
- Consumption reduction rate = Number of cylinders replaced by biogas per month/ estimated rate of LPG consumption × 100.

3. Results and Discussion

3.1. Estimated Gas Yield from Cow Dung Slurry

According to Nijaguna [16], a cow is assumed to produce 10 kg of dung per day, and 1 kg of cow dung produces 0.036 m^3 of biogas. Table 3 presents the estimated gas yield and energy rate of the biogas digester.

Table 3. Energy cost, yield, and rate of the feeding of the biogas digester.

Volume of Biogas Digester (m^3)	Amount of Dung Fed Daily (kg)	Expected Gas Yield per Day (m^3)	Expected Energy Generated (kWh)	Cost of Energy Expected (USD)
2.15	26	1.57	9.42	1.54

From the calculation, 26 kg of wet dung was fed daily to the digester, which produced on average, 1.57 m^3 of biogas per day. Hence, this generates 9.42 kWh of electricity per day, costing about USD 1.54. Recall that the 0.35 m^3 biogas per day can generate 0.324 kWh of electricity, as seen in Table 2. On assumption, 6 kWh of electricity per day is equivalent to 1 m^3 of biogas on average [16]. Regarding the mixing ratio, the rate of water to dilute the cow dung to form a slurry for biogas production is calculated in a mixing ratio of 1:1 waste to water [17].

3.2. Economic Analysis

3.2.1. Initial Total Investment Cost (Fixed Cost)

This involves the summation of the component of investment relating to building, equipment, land and working capital [18]. It is also known as the investment value, which represents the total amount of money spent in the biogas digester. Here, the cost of land was not considered, since the digester was installed in the research center of the FHIT, and land was not bought. Table 4 provides the initial total investment cost (fixed cost) of the fixed dome biogas digester, which involves various items that constitute the digester.

Investment cost (IC) = $\sum$ (investment cost of building, land, equipment and working capital)

Table 4. Total investment cost of the biogas digester.

Material Used	Quantity	Unit Price (USD)	Total Cost (USD)
Cost of fabrication of the biogas digester	1	208.90	208.90
Portland cement (50 kg)	9	5.42	48.83
13 mm concrete stone	1.2 m^3	271.34	325.61
Clinker sp bricks	1850	159.70	295.44
All-purpose sand	1.84 m^3	19.99	36.79
UG rodding eye	1	4.52	4.52
110 mm PVC pipe	1	9.05	9.05
Polyfilla exterior crack filler	1	5.43	5.43
Concrete reinforcing mesh	1	22.61	22.61
Sealant	1	3.62	3.62
Supa lay hold	1	19.90	19.90
Brick force rolls (m^2)	8	1.25	9.99
Gas pipe	1	18.10	18.10
Thermal wool fiber	1	211.93	211.93
Others	1	55.21	55.21
Labor	2	173.74	347.48
Total			**1623.41**

From Table 4, it is revealed that total investment (fixed cost) to install the HDPE biogas digester was USD 1623.41. Although, in the present study, the slurry chamber of the bio-digester was buried underground to utilize the earth's thermal-insulating property and to minimize heat losses (Figure 2). Hence, it provides thermal insulation to the bio-digester. Considering a scenario where thermal insulating material such as the thermal wool fiber (RS PRO super wool fiber) was used, then, the additional cost of USD 211.93 will be part of the investment cost, as presented in Table 4. The thermal wool fiber is known for its excellent insulation from cold to heat. Table 5 presents the economic indicators or parameters used in the study.

Table 5. Study's economic analysis.

Economic Indicators	Values	Units
Total initial investment cost	1623.41	USD
Total income	1160.87	USD
Cost of energy	0.27	USD
Cost of maintenance	324.68	USD
Profitability (ROI)	67.7	%
Payback period	2	years
Net present value	1783.10	USD
Internal rate of return	8.5	%
Discount rate	3.6	%
Annuity	444.49	USD
Cost of annuity	587.77	USD

From Table 5, the project is worth embarking on and is financially feasible based on the data calculated as regards IRR, NPV and ROI. Hence, the high ROI, positive NPV and the above value of IRR against the discount rate shows that the project is accepted. The total revenue or income generated by the project was USD 1160.87, while the total investment cost was USD 1623.41. Looking at the rate of return on investment or return on investment (ROI), it is reported to be 67.7%, which suggests that the project is acceptable and feasible due to its higher cost. In addition, a two-year payback period was calculated as the recovery period; this means the time frame and duration required for the costs used in the project to be reimbursed. From the electricity point of view, the project is expected to generate 0.50 kWh of power that can operate 24 h a day. This produces approximately 9.42 kWh of electrical energy per day.

3.2.2. Annual Operating Cost (APC)

Operating cost refers to expenses in relation to the operation of the project. In this case, it includes the maintenance cost, cost of electricity, labor cost for feeding the digester, and any additional waste cost. It is usually calculated annually following the method in [18]. The costs of energy used in the process are not considered. It is assumed that the energy required for heating the digester is covered by the biogas energy by the digester. The cost of water was also not included, because the water used for the mixing of the substrate was from the tap water supplied by university. Regarding the waste (cow dung), the chemical oxygen demand (COD) value of the cow dung reported was 42,583 g/L. Maize silage is the main animal feed for cows and is known for being rich in energy and supporting higher dry matter intake (DMI) and milk yield. It contains about 30–35% dry matter [19]. The total solid of the cow dung obtained in the study was 13–15%, which is almost half of the maize silage total solids. Hence, the cost of maize silage, inoculum, and other items such as the feed related to the substrate were considered as an operational cost in relation to additional cost of the waste. The pump, which falls under the electricity cost, was also considered as an operational cost.

We considered the cost of maintenance (CM) as an operational cost, which is mostly needed. The cost of maintenance is calculated as 2% of the total initial investment cost divided by the lifetime of the biogas digester [20,21].

$$\text{Cm} = \frac{2\%\ of\ total\ cost\ of\ investment\ (USD)}{No\ of\ years\ of\ the\ system} \tag{11}$$

The cost of maintenance (Cm) is in USD/Year.

The operating and maintenance cost deals with the expenditures spent on labor on an annual basis. For instance, one unskilled laborer is responsible for the feeding and cleaning of the biogas digester and a skilled laborer has the responsibility of managing and performing advanced tasks regarding the system. In addition, the cost at which the gas valve and the pipe are replaced are considered in the cost of maintenance.

Operational cost = $\sum$ (building and equipment repair, labor, raw material, electricity, and water supply). The annual operational costs for the biogas digester are presented in Table 6.

Table 6. Annual operating cost for the biogas digester.

Cost Components	Cost (USD)
Additional cost of waste (maize silage and inoculum etc.)	63.88
Cost of water	N/A
Cost of electricity	35.13
Cost of maintenance and repair	324.68
Total	**423.70**

Considering the cost calculation of the biogas digester, the cost of 5 kg LPG cooking gas in South Africa is approximately R500.00–R900.00 (USD 31.94–57.00) on average. According to Tufaner and Avsar [5], 0.43 kg LPG is equivalent to 1 m^3 of biogas; also, 3–4 cows produced 1 m^3 day^{-1} of biogas. In a year, about 60 kg (12 LPG cooking gas cylinder of 5 kg) will be produced as 140 m^3 (60 ÷ 0.43) biogas equivalent. Table 7 shows the summary value of the cost price of the 2.15 m^3 biogas digester.

Table 7. Cost calculation of 2.15 m^3 biogas digester.

Parameters	Values	Units
Volume of biogas digester	2.15	m^3
Annual biogas production	140	m^3
LPG equivalent value of biogas	60	kg
Investment/fixed cost	1623.41	USD
Annual operating cost	423.70	USD

Focusing on the economic indicator of the project, Table 8 presents some of these indicators in relation to the methane gas content and project lifetime.

Table 8. Discounted payback period with the NPV and IRR on methane price.

Indicators	Values	Unit/Time
Methane gas content	0.085	(USD/m^3)
Discounted payback period (DPP)	2	years
NPV	1783.10	(USD)
Internal rate of return (IRR)	8.5	%
Project lifetime	10	years

The payback periods and net present value (NPV) consider the time value of money for the project lifetime. The NPV calculation is the sum of the discounted future cash flow less the total investment cost (fixed cost). Usually, this is made in the expenditure and working capital of the project. NPV could be positive or negative. Positive NPV indicates that the installation of the biogas digester is possible; hence, the value is created. On the other hand, negative NPV shows that the installation of the biogas digester should not go ahead; thus, it should be disregarded. Zero result of NPV means that no value is created, and therefore, no loss incurred during the project. As the value of the gas price is at USD 0.085/m^3, this yields a positive NPV, with a calculated discounted payback period rate of >10 years, as shown in Table 5. This implies that the installation of the biogas digester is financially feasible. This agrees with Al-Maghalseh [12].

Hence, it is recommended that investing in the installation of a biogas digester project should proceed carefully, considering the current and anticipated future gas rate, according to Al-Wahaibi [6]. On the other hand, internal rate of return (IRR) was employed as a second determinant of profitability. This came to 8%, as shown in Table 8. Assuming a scenario where the NPV is greater than zero and the IRR (8.5%) is greater than the discount rate (3.6%), the realization of the project is profitable to embark on. That means that the installation of the biogas digester will add value. Therefore, the study concludes that NPV and IRR make this possible regarding the benefits of the investments/projects. At this point, the internal rate of return of 8.5% calculated was said to be the rate at which the NPV was generated. Therefore, the rate of return on investment DPP is 2 years. On the other hand, if the IRR is less than the discount rate, then the essence of the project is defeated/destroyed and should not be embarked on. Interestingly, NPV and IRR are two determinants used to evaluate an investment or project.

In Table 9, the calculated amount of biogas can replace approximately 33.2% of LPG gas, which is currently consumed at Solar Watt FHIT for the purpose of cooking only. This value is different from the study conducted by Al-Wahaibi [6], where 28.6% of biogas replaced LPG gas. The discrepancy might be a result of the difference substrate and rate consumption.

Table 9. Calculation on the LPG replacement for cooking purposes.

Amount of LPG in one cylinder (constant)	5 kg/cylinder
Density of LPG	0.54 kg/L at 15 °C
LPG volume in one cylinder (L/cylinder)	9.26 L/cylinder
LPG volume in one cylinder (m^3/cylinder)	0.00926 m^3/cylinder
Expansion rate of LPG (constant)	270
Amount of gas after expansion	2.500 m^3/cylinder
Number of cylinders replaced by biogas per month	1.66 cylinders/month
Estimated rate of consumption of LPG per month for cooking only	5 cylinder/month
Consumption reduction rate	33.2%

4. Conclusions

The essence of this study was to analyze or evaluate the economic feasibility of the HDPE biogas digester, which was installed at the solar watt park of the University of Fort Hare, South Africa. The study was completed because of high cost of construction and installation of biogas digesters. The calculated net present value, profitability, and the annuity was high, which agrees with the literature that the study is favorable, profitable, feasible and acceptable to embark on. The calculated DPP is 2 years, with an NPV of USD 1783.10 and IRR of 8.5%. From the study, it was observed that 33.2% of LPG gas, currently consumed at the study site for cooking only, was replaced with biogas.

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