Techno-Economic Aspects Of Electricity Generation From A School Biogas Digester

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Abstract : This study assesses the technical and economic aspects of electricity generation from school biogas digesters using human wastes as substrate. The study focuses on all rural low-income schools with an enrolment of 300, 500, 700, 900 and 1100 learners respectively. The research is important The schools' total energy demands of 1342kWh, 2082 kWh, 2491 kWh, 2683 kWh and 3093 kWh /month respectively. The designed biogas digesters have volumes of 4 m^3, 7 m^3, 9 m^3, 12 m^3 and 14 m^3 respectively. The profitability values were 35%, 53 %, 56%, 58%, and 59%, respectively. Finally, the payback period values are 2.6 years, 1.9 years, 1.8 years, 1.7 years and 1.6 years respectively. The study is recommended because it will not only provide energy for all rural low- income schools, but also help reduce air pollution, environmental pollution and help the schools to generate some income from selling the biogas.

Keywords: Biogas technology, techno-economic analysis, animal waste, human waste.

1. INTRODUCTION

About 80% of schools in the rural low-income parts of South Africa are subjected to insufficient energy supply [1], high energy bills or no access to energy supply at all [2]. The energy crisis is caused by the socio-economic factors and high population in the rural areas. Most of the rural schools still use pit latrines and landfill sites for the disposal of waste materials and some have farming activities. This study recommends use of renewable energy biogas in rural schools because it is feasible, clean, eco-friendly and cheap [3] and is a solution to the energy crisis faced by the rural schools. The technology will make use of the human waste from the pit latrines to generate clean renewable energy. Biogas technology is way of harnessing energy from human, animal and vegetable wastes [4]. The biogas substrates are excellent sources of energy because the energy is continuously produced [5]. The other benefits of the production and utilization of biogas are environmental and socio-economic [5].

2. BACKGROUND

The biomass is converted to biogas using anaerobic digestion technology [6]. This technology can be the most feasible solution to South Africa's energy needs, especially in the rural low-income parts of the country [7]. The feedstock from cattle, donkeys, goats, sheep, chicken, kitchen waste and human waste in schools can be effectively used to generate biogas energy [8]. The main products in the process are methane, fertilizer and carbon dioxide [9]. The methane is then used to generate heat and electrical energy to power any school and the fertilizer to fertilize the garden [10]. Usage of the biomass to generate energy will guarantee a permanent, consistent, sufficient and affordable energy supply for the schools. Biogas is feasible, clean, eco-friendly and cheap possible solution to the energy crisis faced by the rural schools. [11] The biogas production from the human waste biomass is achieved through the process of anaerobic bacteria in the absence of oxygen inside a digester [12]. There are four main processes that take place inside a biogas plant to produce biogas;hydrolysis,Acidogenesis, acetogenesis and methanogenesis [13]. A biogas digester is an enclosed large tank with gas tank. Different types of digesters were analyzed and the most suitable for this study was found to be the fixed dome digester because of the following factors: the internal gas storage is large; all materials locally available; durability is very high; it's self-agitated and the methane emission is very high; it is constructed underground and saves space [14]. Biogas has an energy value proximately equal to 9 kWh/m^3 of available energy [15]. The aim of this research study is to assess the technical and economic aspects of electricity generation from schools biogas digesters. The success of this study will guarantee a permanent, consistent, sufficient and affordable energy supply for any rural low-income schools and help to reduce air pollution, environmental pollution and help the schools to generate some income from selling the biogas. Job opportunities will also be created for the residents in the construction of the plants and maintenance.

3 METHODOLOGY

3.1 Description of the study area

The study focus is on all rural low-income schools in South Africa with an enrolment of 300, 500, 700, 900 and 1100 learners respectively, as many schools in Mpumalanga province of South Africa have enrolments between 300-1100 learners. South Africa has southern hemisphere weather patterns, with the coldest days from June to August and experiences high temperatures in October to January. Eskom power utility company supplies all schools in the province with electricity. The schools use pit latrines for disposal of human waste. The energy demand at the schools depends on the number of electrical appliances used, the number of each appliance, the wattage of each appliance and the operational hours of the appliance.

3.2 Biogas feedstock

Human waste from pit latrines is the main substrate for biogas production. The estimated volatile feedstock per learner assumed to be 0.02 kg, while the estimated biogas gas yields per kg of waste is 0.054 m^3. These estimated values used to measure the amount of substrate expected from the total number of learners using the pit latrines per day and then calculate the total estimated gas yield per day, and per month.

3.3 Sizing the biogas digester

The amount of feedstock per day determines the size of the digester required. The equations below are used to calculate daily biogas production and digester volume.

Digester volume (m^3)

$$B \approx V = \frac{m}{\rho} \quad (1)$$

Where:
V/B= biomass in kg
m = mass of feedstock in kg
ρ = density= 997.1 kg/m^3

$$V_d = S_d \times Rt \quad (2)$$

Where:
V_d= volume of the digester in m^3
S_d = amount of substrate in kilograms
Rt = retention time in days

$$V_d = (B + W) \times Rt \quad (3)$$

Where:
B = Biomass (kg)
W = Water (liters)

3.4 Gas production rate (G)

The biogas produced was calculated as:

$G = V_s \times G_y$ or

$G = W \times G_y$

Where
V_s is mass of the feedstock per day in kg.
G_y The gas yield per day (m^3)
G The biogas produced (m^3)

3.5 Gas yield for human waste ($\mathbf{G_y}$)

$$G_y = n \times G_h$$

$$G_y = 0.0054 \times \text{ number of learners} \quad (5)$$

Where
G_y – The total gas yield per day (m^3)
G_h – The average gas yield per learner per day which is 0.0054 m^3
n– The number of learners

3.6 Biogas digester design equations

The equations below are used in the design of the digester;

$$(\pi/4).D^2.H = V_s \quad (6)$$

$$D = 2H \quad (7)$$

$$H = (Vs/\pi)^{1/3} \quad (8)$$

$$(3/24).G + V_{sd} = 0.5G \quad (9)$$

$$V_{sd} = 0.375G \approx 0.4G \quad (10)$$

$$(\pi/4)D^2\, d = V_{sd} = 0.4G \quad (11)$$

$$d = (H/3) \times 0.4 \quad (12)$$

$$h + d = 0.85 \quad (13)$$

2 × l × b × h = Vsd = 0.4 G

$$b = (0.2\, G/1.5\, h)^{1/2} \quad (14)$$

$$l = 1.5\, b$$

$$b_{outklet} = (0.4\, G/1.5\, h)^{1/2} \quad (\quad (15)$$

$$Vd = (\pi/6)\, d_h\, .[\, 3(D/2)^2 + d^2{}_h]\;)^4 \quad (16)$$

$$0.6\, G = (\pi/6)\, dh\, .[\, 3(D/2)2 + d2h\,] \quad (17)$$

$$p = 0.75\, D^2 \quad (18)$$

$$q = -0.6(\pi/6)\, G \quad (19)$$

$$R = (p/3)^3 + (\tfrac{q}{2})^2$$

$$A = [(-q/2) + \sqrt{R}]^{1/3} \quad (20)$$

$$B = [\left(-\tfrac{q}{2}\right) - \sqrt{R}]^{1/3} \quad (21)$$

$d_h = A + B$

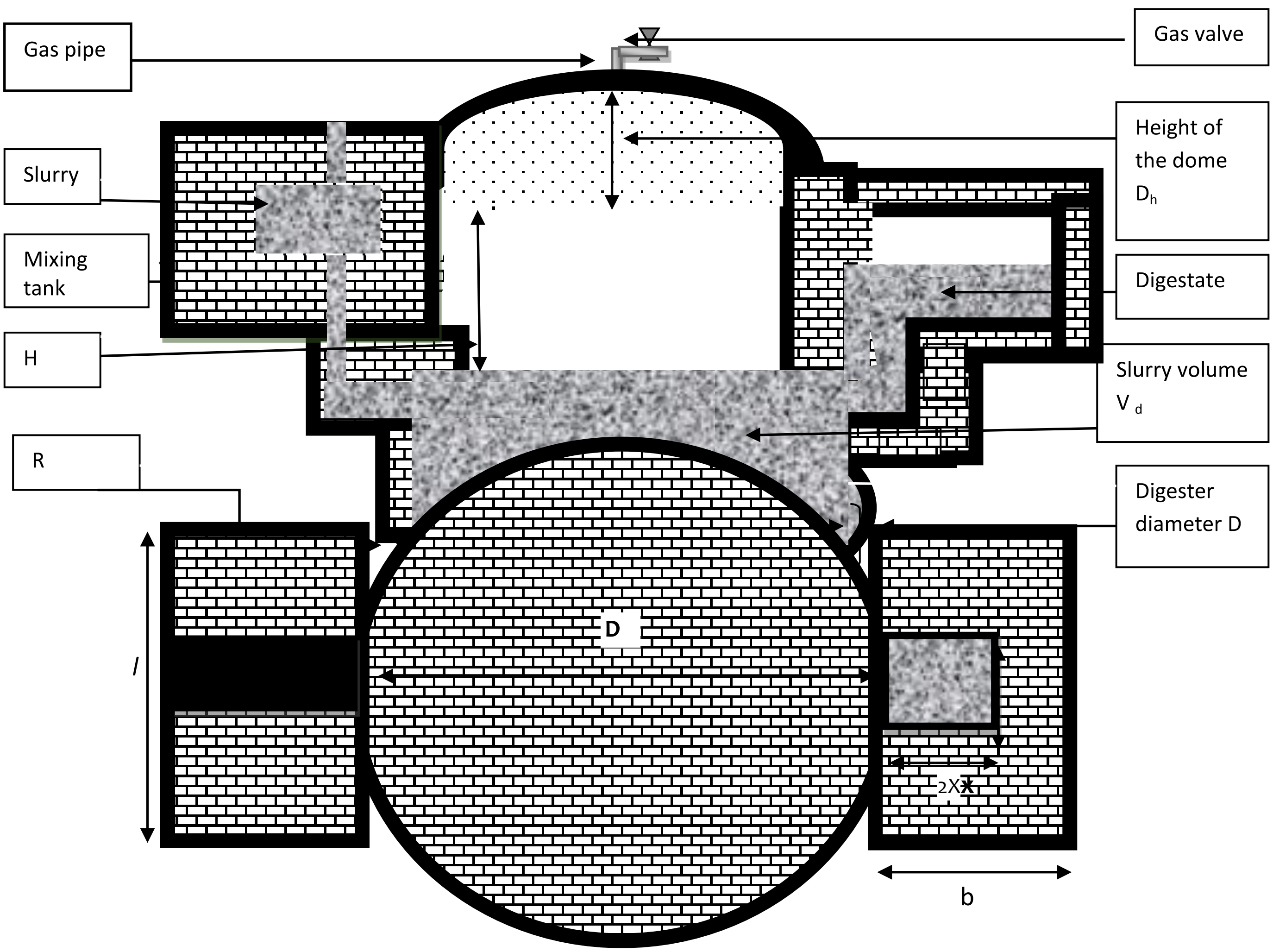
$r = [(d/2)^2 + d^2{}_h]/2\, d_h$ (22)

$(\pi/4).D^2H^1 + 0.6\,G$ (23)

$H' = (H/3) \times 1.9$ (24)

Key
D –diameter of the digester (m).
H –height of the cylindrical portion of the digester up to the top edge of the Inlet/outlet opening (lintel level), for flat bottom digester (m).
H' –same as, H, but for curved bottom digester (m).
D_h –height of the dome (m).
d –Slurry displacement inside digester.
H –Slurry displacement in the inlet and outlet chambers.
R –radius of the dome (m).
L-length of the inlet and outlet chambers (m).
B –breadth of the inlet and outlet chambers (m).
V_s-active slurry (biomass) volume in the digester (m3).
V_{sd}-slurry displacement volume (m3).
V_d-dome volume (m3).
W-weight of cattle dung available per day (kg/day).
G-gas production rate (m3/day).

Figures 1and 2 *show the sectional and the top views of the fixed dome digester.*



The designed digesters from all the typical schools had volumes of $4m^3$, $7m^3$, $9m^3$, $12m^3$ and $14m^3$ respectively.

3.7 Energy demand/ consumption of the school

Total energy demand for the typical schools is measured from the total number of electrical appliances; the consumption is proportional to the wattage of each device and the operational hours. Table 1 shows energy demand for a school A with 300 learners.

TABLE 1
Energy demand for the typical school A with 300 learners.

Load	No.of each device	Power rating (kW)	Operational hours (hour)	Total energy/ Day(kWh)	Total Energy/ Month (kWh)	Cost (Rands)
Electric bulbs	30	0.06	7	12.6	378	387
Kettle	1	2	1	2	60	62
Water pump	1	0.37	12	4.44	133	137
Printers	1	0.33	7	2.31	69	71
Photocopying machines	1	1.5	7	10.50	315	323
Laptops	2	0.1	7	1.4	42	43
Refrigirator	1	0.13	24	3.12	94	96
Microwave	1	0.25	2	0.5	15	15
Electric fans	15	0.075	7	8	236	242
	Total				1342kWh/ month	R1 376

From table 1, the total energy consumed by all the appliances per day is 1342kWh costing R1 376 per month at R1.025 /kWh. Table 2 shows energy demand for a school B with 500 learners.

TABLE 2
Energy demand for the typical school B with 500 learners.

Load	No.of each device	Power rating (kW)	Operational hours (hour)	Total energy/ Day(kWh)	Total energy/ Month (kWh)	Cost (Rands)
Electric bulbs	50	0.06	7	21	630	646
Kettle	1	2	1	2	60	62
Water pump	1	0.37	7	2.59	78	80
Printers	2	0.33	7	4.62	139	142
Photocopying machines	2	1.5	7	21	630	646
Laptops	2	0.1	7	1.4	42	43
Refrigirator	1	0.13	24	3.12	94	96
Microwave	1	0.25	2	0.5	15	15
Electric fans	25	0.075	7	13	394	404
	Total				2082kWh/month	R2 134

From table 2; the school has2 photocopying machines, each of 1.5kW operating for an average of 7 hours a day. The total energy consumed per day is 2082kWh costing R2 132 per month at R1.025 /kWh.Table 3 shows energy demand for a school C with 700 learners.

TABLE 3
Energy demand for the typical school C with 700 learners.

Load	No.of each device	Power rating (kW)	Operational hours (hour)	Total energy/ Day(kWh)	Total Energy/ Month (kWh)	Cost (Rands)
Electric bulbs	70	0.06	7	29.4	882	904
Kettle	1	2	1	2	60	62
Water pump	1	0.37	7	2.59	78	80
Printers	2	0.33	7	4.62	139	142
Photocopying machines	2	1.5	7	21	630	646

Laptops	2	0.1	7	1.4	42	43
Refrigerators	1	0.13	24	3.12	94	96
Microwave	1	0.25	2	0.5	15	15.37
Electric fans	35	0.075	7	18	551	563
	Total				2 491kwh/ month	R2 553

From table 3, the school has 2laptops each with 0.1 kW rating, operating for an average of 7 hours a day. The total energy consumed by all appliances per day is 2 491kWh, costing R2 553 per month at R1.025 kWh. Table 4 shows energy demand for the typical school D with 900 learners

TABLE 4
Energy demand for the typical school D with 900 learners

Load	No.of each device	Power rating (kW)	Operational hours (hour)	Total energy/ Day(kWh)	Total energy/ Month (kWh)	Cost (Rands)
Electric bulbs	80	0.06	7	33.6	1008	1033
Kettle	1	2	1	2	60	61.50
Water pump	1	0.37	7	2.59	78	80
Printers	2	0.33	7	4.2	126	129
Photocopying machines	2	1.5	7	21	630	646
Laptops	2	0.1	7	1.4	42	43
Refrigirator	1	0.13	24	3.12	94	96
Microwave	1	0.25	2	0.5	15	15.37
Electric fans	40	0.075	7	21	630	646
	Total				2 683kWh/ month	R2 780

From table 4, the school has 40 electrical fans, 1 refrigerator and 1 microwave, as part of the electrical appliances, consuming electrical energy. The total energy consumed by all appliances per day is 2 683kWh, costing R2 780 per month at R1.025 /kWh.Table 5 shows energy demand for the typical school E with 1100 learners.

TABLE 5
Energy demand for the typical school E with 1100 learners.

Load	No.of each device	Power rating (kW)	Operational hours (hours)	Total energy/ Day(kWh)	Total Energy/ Month (kWh)	Cost (Rands)
Electric bulbs	100	0.06	7	42	1260	1292
Kettle	1	2	1	2	60	61.50
Water pump	1	0.37	7	2.59	78	80
Printers	2	0.33	7	4.2	126	129
Photocopying machines	2	1.5	7	21	630	646
Laptops	2	0.1	7	1.4	42	43
Refrigerators	1	0.13	24	3.12	94	96
Microwave	1	0.25	2	0.5	15	15.37
Electric fans	50	0.075	7	26	788	807
	Total				3 093 Kwh/ month	R3 170

The table 5 shows that the school has a water pump with 0.37 kW rating operating for 7 hours a day, 50 electrical fans operating for 7 hours and a microwave, light bulbs, printers and photocopying machines. The total energy consumed for all appliances per day is 3 093kWh costing R3 170 per month at R1.025 /kWh.

3.8 Materials required for the digester

TABLE 6
Material requirements for the digester for the school

Item number	Material
1	Cement
2	Galvanized wire
3	Steel rods,
4	PVC pipe110mm,
5	PVC pipe 20mm
6	Coarse sand
7	Gas pipe
8	Bricks
9	Coarse sand
10	Aggregate

The materials required for the digester includes; stone, sand, bricks, binding wires, pvc pipes and galvanized wires as shown in table 6.

3.9 Techno- economic analysis

The techno-economic analysis for the project was used to evaluate the favourability and profitability of the biogas investment project. The economic indicators considered were the investment costs, the liquidation yield, the total operational costs, total income and revenues, cost comparison, cost annuity comparison, profitability, static Pay Back Period (PBP), Net Present Value (NPV) and Internal Rate of Return (IRR).

3.9.1 Investment cost of the project

The total investment costs was calculated and recorded on table 11 on the results section.

3.9.2 Static payback period

Static payback period (SPB) refers to the time it takes to recover the capital invested in the project [17]. Equation 30 was used to calculate the payback period, and results are recorded on table 11.

$$\mathrm{SPB} = \frac{\mathrm{CI}}{\mathrm{AR}} \qquad (30)$$

Where:

SPB– Payback period in years.
CI- Capital invested
AR- Annual Returns

3.9.3 Net present value (NPV)

The net present value depends on the interval of time between now and the cash flow. It is the difference between the present value of cash inflow and the present value of the cash outflows over a period [18]. A discount rate of 13% was used, the life span of the digester is assumed fifteen years. The net present value was calculated using the NPV formula.

$$\mathrm{NPV} = -I_0 = (\mathrm{AR} \times \mathrm{PF}) + L_T \times q^{-T} \qquad (31)$$

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{\mathrm{NCF}_t}{(1+k)^t} - \mathrm{NCF}_0 \qquad (32)$$

Where:

NPV- Net Present Value
I_0- Investment cost
AR – Annual Return
PF- is the present value factor in years
L_T- Liquidation yield at the end of the service life in years
q^{-T}- Discount factor in years
NCF_t- Net cash flow generated by the project over time t
NCF_o –Initial cash outlay on project
N – Life of the project

3.9.4 Profitability

Profitability or return on investment (ROI) is the degree to which the project yields profit [19], [20]. Therefore, the calculations were based on equation (33).

$$\mathrm{ROI} = \frac{\mathrm{ANP}}{K_A} \times 100 \qquad (33)$$

Where, ROI –Return on investment
ANP –The average net profit per time
K_A – Average capital investment

3.9.5 Revenues

The total income made was recorded in table 11, the results section. Equation (34) was used to calculate the annual income made from the sales.

$$\mathrm{REVENUE\ (INCOME)} = \mathrm{R}1.025 \times 12 \times 500\mathrm{kWh} \qquad (34)$$

4. RESULTS AND DISCUSSIONS

4.1 Biogas feed stock

The feedstock for the biogas production was human waste from schools with enrolments, 300, 500, 700, 900 and 1100 learners respectively.. The estimated average volatile feedstock per person per day was 0.018 kg, while the biogas generated per person was 0.054 m ^{3}. Table 7 shows the measured feedstock, the biogas yield person per day and the total biogas produced per day.

TABLE 7
Feedstock and gas yield.

Total number of learners	Gas yield m^3/kg	Feedstock / learner/ day. kg	Feedstock/ day for all the learners kg	Gas yield /learner /day m^3	Total gas yield per day m^3	Total energy produced/ month(kWh)
300 learners	0.006	0.018	5.4	0.054	16.2	4374
500 learners	0.006	0.018	9	0.054	27	7290
700 learners	0.006	0.018	12.6	0.054	37.8	10206
900 learners	0.006	0.018	16.2	0.054	48.6	13122
1100 learners	0.006	0.018	19.8	0.054	59.4	16038

Each learner can produce an average of 0.054 m^3 of biogas per day as recorded in table 7. Assuming that 1m^3 of biogas produces 9 kWh of energy; The total energy produced in School A, B, C, D and E respectively are; 4374 kWh/month, 7290 kWh/month, 10206 kWh/month, 13122 kWh/month and 16038 kWh/month respectively. The schools will have excess energies of 3032 kWh/month, 5208 kWh/month, 7715 kWh/month, 10439 kWh/month and 12945 KWh excess energy that part can be sold at R1.025/KWh and make an income of around R6 150/ annum if 500 kWh is sold /month.

4.2 Sizing the biogas digester

It was assumed that the average life weight of each human at the school was 60 kg. Table 8 shows the calculations for the dimensions of the fixed dome digester.

TABLE 8
Calculated values of parameters the fixed dome digester

Parameter	Symbol	Calculated value				
Digester size (m^3)		4 m^3	7m^3	9 m^3	12 m^3	14 m^3
Diameter of the digester (m).	D	3.44	4.10	4.60	5.0	5.30
Height of the cylindrical portion of the digester	H	1.72	2.05	2.30	2.50	2.66
Height of the curved bottom digester (m).	H'	1.08	1.30	1.46	1.58	1.68
Height of the dome (m).	D_h	0.02	0.02	0.01	0.01	0.01
Slurry displacement inside digester.	d	0.23	0.27	0.31	0.33	0.36
Slurry displacement in the inlet and outlet chambers.	h	0.62	0.58	0.54	0.52	0.49
Radius of the dome (m).	R	26.1	74.3	148	246	359
Length of the inlet and outlet chambers (m).	l	0.38	0.51	0.62	0.71	0.81
Breadth of the inlet and outlet chambers (m).	b	0.25	0.34	0.41	0.47	0.54
Active slurry (biomass) volume in the digester (m^3).	V_s	16	27	38	49	59
Weight of substrate available per day (kg/day).	W	0.018	0.018	0.018	0.018	0.018
Gas production rate (m^3/day).	G	0.29	0.49	0.68	0.87	1.07
Radius of the dome (m)	r	74	105	264	312	354

The size of the digester depends on the amount of volatile solid available per day per school and they are; 16m^3, 27m^3, 38m^3, 49m^3 and 59m^3 respectively. The size of the digesters (V_d) for school A, B, C, D and E are; 4m^3, 7m^3, 9m^3, 12m^3 and 14 m^3 respectively. From Table 8, the diameters of the digesters are 3.44 m, 4.10 m, 4.60 m, 5 and 5.30 m respectively.

4.3 Energy demand of the school

Table 9 shows total energy demand for different schools, A, B, C, D and E with enrolments previously mentioned..

TABLE 9
The total energy demand for schools A,B,C,D and E.

Energy demand areas	Total energy / month				
Schools	A	B	C	D	E
ADMIN BLOCK/kWh	904	1313	1312	1300	1300
CLASSROOMS/kWh	409	740	1150	1354	1764
SECURITY ROOM/kWh	29	29	29	29	29
TOTAL /kWh	1342	2082	2491	2683	3093
Total cost / month	R1 376	R2 134	R2 553	R2 780	R3 170

Table 9 shows that the total energy demand for school A per month is 1342kWh and most of the energy consumed in the administration block. Furthermore, school B has a total energy demand of 2082 kWh per month and finally school C, D and E have total energy demands of 2491kWh, 2683kWh and 3093kWh per month respectively. This study will rescue the rural low-income schools from high electricity bills from Eskom since they will use biogas as a source of electricity for lighting, heating and cooking purposes. In addition, it will lead to climate mitigation since methane from biogas is converted into energy. The study will also create some job opportunities for the residents around in biogas construction, biogas maintenance and feeding.

4.4 Materials required for the digester

Table 10 shows the material estimates for the fixed dome biogas digesters.

TABLE : 10
Material estimates for the fixed dome biogas digesters.

Building materials

Description	SI unit	Unit price	4 m^3 Quantity	4 m^3 TOTAL	7 m^3 Quantity	7 m^3 Total	9 m^3 Quantity	9 m^3 Total	12 m^3 Quantity	12 m^3 Total	14 m^3 Quantity	14 m^3 Total
Stones	m^3	R250	2	R500	3	R750	5	R1 250	6	R1 500	7	R1 750
Bricks	no	R0.50	5256	R2 628	9201	R4 600	11826	R5 913	15768	R7 884	18396	R9 198
Coarse sand	m^3	R365	4	R1 460	5	R1 825	7	R2 555	9	R3 285	12	R4 380
Portland cement	bags	R71	24	R1 704	42	R2 982	54	R3 834	62	R4402	84	R5 964
Gas pipe turret pipe	pcs	R130.	1.0	R130	1.0	R130	2	R260	2	R260	3	R390
Steel rods 8mm	pcs	R35.	3.0	R105	4.0	R140	6	R210	8	R280	9	R315
Binding wire	kg	R34.95	1	R34.95	1	R34.95	2	R70	2	R70	3	R105
Galvanized wire	kg	R34.95	1	R34.90	1	R34.95	2	R70	2	R70	3	R105
PVC pipe 110mm	PCS	R148.	1	R148	1	R148	2	R296	2	R296	3	R444
PVC pipes 20mm	pcs	R13.95	4.0	R56	5.0	R70	7	R98	9	R126	10	R140
Total				R6 801		R10680.		R14 556		R18 173		R22 789

The total number of bricks required for the digester in a school with 300 learners is 5256, costing R 2 628 at R0.50 per brick and 24 bags of cements will be required as well as 4 m^3 of sand as shown in Table 10. The total investment cost for the project is R6 801 for school A with 300 learners. for the school with 500 learners; 9201 bricks costing R11 826, 42 bags of cement costing R2 982 and a 5 m^3 of sand required. School with 700 learners will require 11 826 bricks costing R 5 913, 54 bags of cement costing R3 834 and 7 m^3 of sand required. School with 900 learners requires 15 768 bricks costing R7 884, 72 bags of cements costing R5 112 and a 9 m^3 of sand. Finally the school with 1100 learners will require 18 396 bricks costing R9 198, 84 bags of cement costing R5 964 and of 12 m^3 sand, as shown in Table 10.

4.5 techno-economic analysis of the project

The investment costs for the digesters were calculated and the results are summarised in Table 11. Table 11 shows the techno-economic analysis data for the investment project.

TABLE : 11
calculated parameters for the typical school

Parameter	Calculated value (R) for digester sizes				
	4 m^3	7 m^3	9 m^3	12 m^3	14 m^3
Investment cost	R6 801	R10 680	R14 556	R18 883	R22 789
Operating cost	R27 000	R27 300	R30 000	R31 000	R31 000
Maintenance	R2 300	R2 400	R2 500	R2 600	R2 700
Labor cost	R5 000	R5 200	R5 400	R5 500	R5 700
Energy related	R2 000	R2 200	R2 300	R2 400	R2 400
Revenues(unfixed sales)	R6 150	R6 150	R6 150	R6 150	R6 150
Other incomes (savings)	R16 512	R25 608	R30 636	R33 360	R38 040
Total capital cost	R43 101	R47 780	R54 756	R57 383	R64 589
Profitability	35%	53%	56%	58%	59%
Payback period	2 year 6 months	1 year 9 month	1 year 8 month	1 year 7 month	1 year 6 month
NPV	R63 605	R117 708	R143 225	R158 202	R181 239

From Table 11, the total investment cost for school A is R6 801 and the profitability is 35%, the static payback period is 2.6 years with Net Present Value of R63 605. For school B, the total investment cost is R10 680, the profitability is 53% and the payback period is 1.9 years with Net Present Value of R117 708. For school C, the total investment cost is R14 556, the profitability is 56% and the payback period is 1.8 years with net present value of R143 225. For school D, the total investment cost is R18 883, the profitability is 58% and the payback period is 1.7 years with net present value of R158 202. Furthermore, for school E, the total investment cost is R22 789, the profitability is 59% and the payback period is 1.6 years with a Net Present Value of R181 239. In addition, the schools can also sell part of the excess energy to the neighboring schools at R1.025/kWh and get an average of R6 150 if 500 kWh of energy is sold per month. From the results, it can be depicted that a school with a high enrolment has more biogas from its feedstock. From the results, the payback periods are less than three years to show that the biogas investment projects are profitable and are worth doing.

5. CONCLUSION

From the findings of the study, the biogas technology is very easy to execute, since the main resources are freely available in the rural low-income schools in the country. The schools would also be able to generate some income by selling part of the energy generated to the neighboring schools and community at a cheaper price. The generation of electricity from biogas by each school will give the schools some energy freedom, since they will be free from the high electricity bills from Eskom. The average payback period for the investment project is 2years with a profitability of 50 % average. The execution of technology is profitable and favorable in any school in the country that falls within an enrolment of 300 -1100 learners. Adopting the biogas technology in the country will not only benefit the schools, but the community as a whole by providing a clean, cheap renewable energy. From the analysis, the bigger the school, the more biogas production and money savings with income from sold excess biogas. With reliable access to energy, the rural low-income schools in the country will finally be able to embrace the fourth industrial revolution with pride. It is about time, the rural low-income schools shift from being consumers to being producers.Finally, the payback periods for all schools were less than three years to show the profitability and favourability of the investment projects. Therefore, the biogas technology projects are worth doing in all schools.

6. RECOMMENDATIONS

This study recommends use of renewable energy biogas in rural schools because it is feasible, clean, eco-friendly and cheap. Since the efficiency of biogas production depends on the amount of substrate and the temperature inside the digester, the study recommends use of solar modules that will collect solar energy and convert it to heat energy that will heat the biogas digesters to the required temperature so that the production rate of biogas is fast and consistent.

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