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The Potential of Local Materials on The Manufacturing Cost of A Cylindrical Floating Digester To Produce Biogas

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ABSTRACT: This work aims to study the impact of using local materials on the manufacturing cost of a cylindrical floating digester. Black basalt stones cut, several stones uncut and sheets have been chosen. During construction the gas tank is built from two types of metal. The black sheets of 15/10 and 8/10 obtained from ordinary metal drums of 200 L. The results show that a modified cylindrical digester gas tank float was built with stone. Its volume is 25m^3, its diameter and height are respectively 3.2 m and 3.1 m. The biogas tank is capable of storing 9.8 m3 of this one. The average quantities of other materials like cut stones, various stones, sand are respectively 0.88, 0.62 and 0.484 ton/m^3 digester. The use of sheet 8/10 recovered from metal drums is not appropriate. The financial evaluation shows that the construction work cost is approximately 52.000CFA/m^3 digester. Using local materials reduces the cost of construction of a biogas unit.

Keys words: local materials, stone, sheets, digester, cost of construction, biogas

I. INTRODUCTION

Worldwide, energy is based on government priorities and concerns of the public. Indeed, the energy hub of any industrialization is a prerequisite for economic development (Renewable Energy Policy Network for the 21st Century - REN21-2005; World Health Organization-WHO-2008). Therefore, the constant search for well-being through development policies has been increasing dramatically the energy requirements (Tippayawong *et al*. 2007; Gerät, 2008). However, conventional energy (oil, coal, natural gas) main sources of supply are becoming increasingly scarce and therefore expensive. In addition, predictions based on current consumption rates predicted depletion in a few decades (Diop, 1985; Ysengrin, 2005; Gerät, 2008). However, Yevgeny (2006), REN21 (2005) and the Agency for Environment and Energy Management-ADEME-(2006) estimate that over two billion people worldwide still lack access to these energy sources. For example in the region of the Far-north of Cameroon, only 0.2% of the population has access to cooking gas (National Statistics Institute-NSI-2004). Furthermore, consumption of oil is largely responsible for climate change that plunges the international community in disarray (Caussade, 2006; Gerät, 2008). It is therefore urgent to seek other appropriate energy sources.

In addition, the inaccessibility of part of the human population to traditional or conventional energy makes them ipso facto dependent on firewood. In this regard, REN21 (2005) confirms that approximately 2.4 billion people in developing countries depend on the use of solid biomass for food into energy. Yet this energy source creates as many problems as it solves. For example, it is the cause of over 1.6 million annual deaths of women and children due to the pollution caused by smoke (WHO, 2008). In addition, he was assigned to collection of firewood in the forest the main cause of loss of 64 million hectares of forest in Africa between 1990 and 2005 (Institute of Science in Society-ISIS-2006). This contributes indirectly a part in climate change and secondly to the vicious circle of poverty (REN21, 2005).

Finally, current trends of global warming are undeniable. Indeed, it was recorded a significant increase in the average temperature of the earth's surface. It is estimated at 0.74 ° C / year and could reach 1.4 to 5.8 ° C (Agu et al, 2007; Gerät, 2008). It is recognized that greenhouse gases from human activities are the main cause of the observed warming (Diop, 1985; Greenfacts, 2006). Methane captured by the biogas technology, is the second polluter of the atmosphere after carbon dioxide (Agu et al., 2000, Breuil, 2007). According to forecasts, the warming trend should continue and intensify over the next century and beyond. The consequences have been adverse effects which are also measurable in the natural and human systems. Faced with this situation, adaptation measures have presented enough limits. For this purpose, the mitigation measures to reduce the emission of greenhouse gases seem to be the most appropriate solution. Among other things, it comes to investing in technologies that can provide clean energy source that can substitute fossil fuels (Greenfacts, 2006; Caussade,2006).

From the foregoing it is clear to see that humanity faces a triple challenge essential for survival. The first is to fight against global warming by targeting the issue of greenhouse gas emissions. Thus, reducing the emission of methane is a special way of international priorities. The second challenge is to gradually replace fossil energy with new sources cleaner and more accessible. The latter would avoid the ecological disaster that could result in an increasing concentration of greenhouse gases in the atmosphere. The third is to provide the rest of the world's population depending on firewood another energy source that can reduce deforestation. Awareness explicitly calls upon all to promote technology to minimize the impacts mentioned above. Biogas technology is as a tool that can contribute effectively to the challenges mentioned above (Tippayawong *et al.*, 2007). However, it remains very little control and popularized in Africa and Cameroon particularly, at this time when the need becomes increasingly urgent. Indeed, the success of a biogas production unit requires an ability to analyze the parameters of anaerobic digestion to create a medium required. But it lacks drastically technicians with expertise in this technology. Moreover, the high cost of building a digester makes it very accessible to people (Hammad et al. 1999; N'goran, 2005). However, this cost can be substantially minimized by using locally available materials (Abura *et al.*, 1996). In addition, the inability to make a choice techno-economic leading to the appropriate shape of the digester increases the risk of rupture of structure and cost of investment (Gesellschaft für Technische Zusammenarbeit-GTZ, 1989). With this in mind, two main issues emerge:

- How the promotion of biogas can contributes to improving living conditions locally and globally?
- What type of devices should be designed and installed so as to provide economic biogas that is only for cooking? These questions lead us to identify the targets below.

The main objective of this study is to produce biogas from a digester built in stone. More specifically, they are:

- Designing the device for producing biogas;
- Build the device;
- And finally, test its operation and perform financial analysis of investment.

II. MATERIALS AND METHODS

2.1-Design of a Biogas Production Unit

2.1.1-Evaluation of physical design parameters

Evaluation of physical design parameters of the biogas were made based on collecting information related to different temperatures in the locality of study and evaluation of the amount of available raw materials of the work area. This evaluation was performed according to the method proposed by GTZ (2008). The locality selected for the work was Kumba-Cameroon. According to GTZ (1989), the temperature in the digester area Kumbo would be about 23 ° C. As the substrate, the cattle manure was collected during the construction of the project. The C / N value of a substrate is one of the main factors limiting the anaerobic digestion. According to GTZ (1988), cattle manure has a C / N with 25. This value is for the appropriate interval, which varies from 20 to 30.

2.1.2-Estimating the demand for biogas

The estimating demand for biogas is evaluated by equation (1):

$$Q_g = nq_m \quad \left(m^3/j\right) \qquad (1)$$

Where :

Q_g is demand of the structure for the biogas;
n is the number of people to feed;
q_m is the maximum need of biogas daily per person.

2.2-Sizing unit

2.2.1-Volume calculations

2.2.1.1-Volumetric flow

Volumetric flow is the daily quantity Q in m^3 of cattle manure diluted in water used to feed the digester for production of Q_g quantity of biogas. In this regard, Maringa and Kuria (2008) state that at this temperature, an average of 6.2 kg of beef manure can produce 340litres of biogas per day. The dilution is made after the ratio of 1 kg of manure per 1.5 liter of water. According to GTZ (1988) and GTZ (1989), 1kg of manure diluted in 1.5 liter of water is equated to 2.5 liters of substrate. Thus, is given by the following formula:

$$Q = \frac{6,2\left(1+1,5\right)Q_g}{340} \text{ or } Q = 0,0455Q_g \quad \left(m^3/j\right) \qquad (2)$$

2.2.1.2-Volume of digester

The volume of the digester is a main factor in designing a production of biogas. It is a function of hydraulic retention time TRH and flow volume of the substrate (Q). This volume is given by the formula:

$$V_d = T_{RH} \times Q \quad (m^3) \qquad (3)$$

Where:

V_d is volume of the digester

T_{RH}: Hydraulic retention time;

(Q) : flow volume of the substrate.

2.2.1.3-Volume of the gas tank

To calculate the volume of gas (V_g) stored, it must determine the periods (P_i) of daily consumption and duration (t_i). Then, deduct the average hourly production (Q_{pmh}) and consumption average hourly biogas (Q_{cmh}).

According to GTZ (1988), the volume of biogas produced during the day and night is almost the same. During the hours of consumption, biogas also occurs. For this purpose, only the difference between Q_{cmh} and Q_{pmh} is important to assess the volume of biogas to be stored for a period of consumption. Thus, it is calculated a volume V_1 of biogas to be stored to satisfy the longest duration (T_i) of use. These various quantities are given by the following formulas:

$$Q_{cmh} = \frac{Q_g}{\sum t_i} \quad (m^3/h) \qquad (4)$$

$$Q_{pmh} = \frac{Q_g}{24} \quad (m^3/h) \qquad (5)$$

$$V_1 = (Q_{cmh} - Q_{pmh}) T_i \quad (m^3) \qquad (6)$$

And replacing equations (4) and (5) in the equation (6) the equation becomes:

$$V_1 = \left(\frac{24 - \sum t_i}{24 \sum t_i} \right) Q_g \times T_i \quad (m^3) \qquad (7)$$

On the other hand, we must determine the volume V_2 of the biogas produced during the longest period between two successive periods of consumption.

$$V_2 = Q_{pmh} \times T_z \quad (m^3) \qquad (8)$$

Where:

T_z is the duration of this period.

The volume of the tank size is:

$$V_g = max(V_1, V_2) \times 1,25 \quad (m^3) \qquad (9)$$

2.2.1.4-Pretreatment tank volume

The pretreatment tank is where the substrate crude is diluted in water and then homogenized sufficiently before it enters the digester. V_p is the volume of this reservoir, it is recommended that it be 1.5 to 2 times the flow volume of the substrate (GTZ, 1989). In this study, we chose a factor of 1.5.

$$V_p = 1,5Q \quad (m^3) \qquad (10)$$

The shape of the digester depends on the ratio (r) of the volume of the digester on one of the gas tank.

$$r = \frac{V_d}{V_g} \qquad (11)$$

2.2.2-Calculation of diameter and height
2.2.2.1-Digester
2.2.2.1.1-Diameter (D_d) and height (H_d)

Consider Volume of digester in m^3. It consists of two geometric figures that their volumes are
The modified base similar to a cone has a volume given by equation:

$$V_b = \frac{\pi D_d^{\ 2} \times H_b}{12} \quad (m^3) \qquad (12)$$

In this modified form, the height H_b of the conical base used is $D_d/10$, Thus,

$$V_b = \frac{\pi D_d^{\ 3}}{120} \quad (m^3) \qquad (13)$$

The volume of the cylindrical overcoming this basis is:

$$V_c = \frac{\pi D_d^{\ 2} \times H_d}{4} \quad (m^3) \qquad (14)$$

In cylindrical shapes, it is recommended that the height is relatively equal to the diameter (Kuria and Maringa, 2008, GTZ, 1988).
Thus, it was considered that $D_d = H_d$
The total volume of the digester is expressed as follows:

$$V_d = V_b + V_c$$
$$V_d = \frac{31}{120}\pi D_d^3 \quad (m^3) \qquad (15)$$

Therefore, its diameter is given by the following equation:

$$D_d = \sqrt[3]{\frac{120 V_d}{31\pi}} \quad (m) \qquad (16)$$

2.2.2.2-Biogas tank
2.2.2.2.1-Diameter

The tank floats in a groove arranged in water from a slit in the middle of the digester.
The diameter D is:

$$D_r = D_d + 2E_p + l_g \quad (m) \qquad (17)$$

2.2.2.2.2-Height H_r

Knowing the volume V_g of the reservoir, the height H_r is given by:

$$H_r = \frac{4V_g}{\pi D_r^2} \quad (m) \qquad (18)$$

Furthermore, the roof of the tank is designed on a slope of 20%. This location is a compromise between a quantity of biogas stored and inoperative but the danger posed by standing water on the roof of the tank. It is more efficient to have a pretreatment tank of cylindrical shape. This form facilitates the process of homogenization of the substrate diluted in water. This during the height (H_p) of the cylinder is chosen so that the use of a blender (stick) through the inlet pipe is possible.

The diameter $\left(D_p\right)$ is given by the following relation:

$$D_p = \sqrt{\frac{4V_p}{\pi H_p}} \quad (m) \qquad (19)$$

By replacing the equation Vp in equation (19), it gives:

$$D_p = \sqrt{\frac{6Q}{\pi H_p}} \quad (m) \qquad (20)$$

2.3-Choice and installation of pipes

The feed lines (input) and discharge (output) of the digester pipes are polyvinyl chloride (PVC) with 200mm diameter. According to GTZ (1988), the minimum diameter of 100mm when the substrate is liquid. However, a pipe of larger diameter enables the blending of the substrate in the digester from a stick. As for the pipes to biogas, it was used PVC pipes to 32mm. Indeed, the pipes of this type are suitable for the supply of biogas. As for the installation of gas pipes, it must at least provide two water traps. They can discharge a large quantity of water droplets contained in the gas. Thus, a trap is installed at the outlet of the digester and another just before the point of consumption of biogas. In each of these points, we also place a valve. And when the supply network has an irregular slope, additional traps will be installed. For this purpose, a water trap is fitted at the lowest point of each section where the slope has a discontinuity (GTZ, 1988). The pipes, in part 6m are connected with the Tangit PVC-U.

2.4-Stability study of the digester

A single underground digester is subject to two main forces. The first is the hydrostatic pressure (W) exerted by the liquid in the digester on vertical walls. The second pressure (E) is that exerted by the surrounding land on the same wall structure (Sanglerat et al. 1983; Ranald, 1988, GTZ, 1988). As part of the slurry, the liquid characteristics are similar to those of water. According Ranald (1988) hydrostatic pressure is calculated using the following formula:

$$W = \frac{\delta_e {H_e}^2}{2} \quad (kPa) \qquad (21)$$

The earth pressure on the structure, Strap et al. (1983) estimated from the formula below:

$$E = \frac{\delta_t \times \beta \times {H_t}^2}{2} \quad (kPa) \qquad (22)$$

2.4-Technical drawings of the biogas unit

2.4.1-Digester

From previous calculations, the digester was designed. The book is almost underground, is stabilized by the balance of hydrostatic pressure and earth. But the concrete in compression resists. As a result, the thickness of the book serve to seal (Charon, 1986). In this case, the GTZ (1989) uses a thickness of 20cm for the digesters throat without water volume less than 10m3 masonry rubble. The digester is shown in Figure 1

2.4.2-Pretreatment tanks and discharge

The reservoir base pretreatment is above the maximum level reached by the substrate in the digester. Minimum height differences observed between these two points is 30cm (GTZ, 1988). As for the discharge tank, the top is to 8cm below the maximum level that can reach the substrate in the digester. The tank discharge depends on the value of the substrate. To this end, it is incidental. In this study, it has a volume of 2m3 in order to store the daily discharge. These two types of tanks designed are shown in Figure 2

2.4.3-Biogas tank

The tank enters the digester through the middle of the gorge water. Knowing the characteristics of the digester, and the equations for determining the diameter and height of the tank. The different parts of the latter designed to store 9.84 m3 of biogas per day are illustrated in Figure

2.5-Construction Unit Simple Biogas Production

2.5.1-Excavating

The excavation of land is the first stage of construction. The diameter of the area to be excavated is equal to the digester plus (GTZ, 1989).

The volume V_t of earth to dig is given by the following formula:

$$V_t = \frac{\pi H_{ex}\left(D_d + 2\times 0,5\right)^2}{4} \quad \left(m^3\right) \qquad (23)$$

The excavation is conducted at a depth H_{ex} of 2.9 m. The corresponding volume of soil according to the equation (26) is 36.42 m3. This work is done by using picks, shovels, a tape measure. Figure 3shows some stages of the excavation.

2.5.2-Construction of digester

The digester is built in stone. It was used two types of stone: the basalt stones (black) cut and different uncut stones. The level of cement required to seal according to Charon (1986) is 350 to 400 kg/m3. To maximize the safety threshold, the construction is carried out according to the dosage of 400 kg/m3. The walls are raised by two technicians with experience in construction of water reservoirs. The work was made possible through the use of mason and water levels, trowels and tape measure. The main steps of the actual construction are the foundation, raising walls, and plaster.

2.5.3-Fondation

The main steps of the foundation are illustrated in Figure 4

2.5.4-Building walls

Important steps in the construction of the walls are: the laying of the first level of cut stone, the setting of inlet and outlet, the construction of the water throat and construction of the partition wall.

2.5.5-Coating

The coating is essential to seal the tank (Charon, 1986). According to Blondin et al. (1993), it is done at three different layers. The first has the thicker the same strength as concrete. As part of this work, the first, second and third layer respectively have a thickness of 3cm, 1.5 cm and 0.5 cm. The second layer is performed two days after the first. The first two layers have the same strength as the cement walls. The third has a dosage of 350 kg/m^3.

2.5.6-Construction of tanks and pretreatment discharge

The discharge tank is constructed with stone, while that of pretreatment is cinderblock smashed.

2.5.7-Construction of the gas tank

The gas tank is built mainly from two types of metal. The black sheets of 15/10 and those of 8 / 10 obtained from ordinary metal drums of 200l. However, the sheets 25/10 and 20/10 are those recommended. 35x35 angle bars and galvanized pipe 60mm helped strengthen and build the tank at the same time the mixing system. The end of construction is to protect the metal against rust. To this end, two coats of rust and two coats of oil paint were applied. GTZ (1988) and Kuria and Maringa, (2008) recommend the red and black paint which promote the conservation of heat.

2.5.8-Biogas supply system

The supply network of biogas is 120m long. It has four water traps: two conventional traps and two additional traps.

2.6-Test operation of biogas and Financial Analysis of Investment

2.6.1-Operation test of biogas

2.6.1.1-Test the tightness of the digester tank of biogas and biogas supply system

The seal in a biogas production unit is the first sign of success. Thus, GTZ (1989) and FAO (1986) recommend a test performed. To test the tightness of the digester, it is filled with water and left for 24 hours, time necessary for the walls are saturated with water. Then add water to the digester to its original level. A day later, the volume of water lost is valued. The digester is declared tight when the amount lost is less than 2% of its original volume. With regard to the biogas tank, the leakage inspection was conducted by two methods. The first was to fill the water tank for evidence of leakage point. Another is using soap and water when the tank was carefully installed in the digester. To this end, the water is applied to a surface of biogas tank is out of the water of the gorge. Thus, it is possible to identify bulbs air escaping at the leak. The latter method is effective only when the reservoir has already biogas. The ISOPON P38 and putty used to seal holes identified.

As to the supply network, installed the pipe was filled with water and left for 24 hours. After this time, an inspection along the line to identify points of water forming wet probable points of leakage of biogas.

2.6.1.2-Test temperature of the digester

The digester temperature is the critical factor of methane measured during this study. From a digital thermocouple HH-99A-T1, ambient temperatures at ground level and at two different points in the digester previously filled the substrate are measured. In the digester, decision is made at 0.3 m and 1.5 m from the base. To this end, the sensor wire was installed in a stable at 1.5 m in the digester. The other end of the wire appears to the outside where it can be connected to a thermocouple. For cons, the temperature at 0.3 m is taken by successively recording the times, another sensor wire into the digester through the discharge pipes and power. The average of the two recorded data is regarded as the temperature at this point. The measurements are performed at six o'clock in the morning, 12 hours and 18 hours for 16 days. The data collected provide evidence of changes in temperatures.

2.6.1.3-Production and consumption Test of biogas

According to GTZ (1988), the quantities of biogas produced and consumed can be estimated from the variation of the height of the reservoir above the biogas digester. For consumption, we measured the height every five minutes during a period of 3hours 30minutes per day over a period of one week. To assimilate a situation of maximum flow of biogas from the point of consumption, all the valves were fully open. As for production, the tank height is measured every 15 minutes for eight hours a day for a week. During these hours, the biogas is not consumed. It has also been recorded time and the amount of biogas to cook some meals in the center.

Production $\left(Q_p\right)$ or consumption $\left(Q_c\right)$ during a defined period is given by the following formula:

$$Q_{pmh} = A\Delta H \qquad \left(m^3/h\right) \qquad (24)$$

$$Q_{cmh} = A\Delta H + Q_{pmh} \qquad \left(m^3/h\right) \qquad (25)$$

2.7-Financial Analysis of Investment

2.7.1-Financial statements of the project execution stage

It consists of inventories of material and financial work performed. It concerns the construction of the digester tank pretreatment and discharge of biogas tank and installation of water supply network to biogas.

2.7.1.1-Annual revenue production of biogas

This paragraph assumes that the biogas produced substituted butane gas that would buy the market BIOFARM Kumbo to prepare meals for students. According to GTZ (1988) and Igoud (2002), a cubic meter of biogas is equivalent to 0.4 liters of butane. In this regard, the biogas is converted into 12.5 liter bottle of butane gas on the market. The annual revenue from the production of biogas is thus determined by the formula.

$$R_t = \frac{365 \times 0,4 Q_{pmj}}{12,5} \times P \qquad (26)$$

2.7.1.2-Payback period of investment

The payback period (PPI) is the time after which the investor can recover their capital. That is to say, the combined net profits are expected to equal the initial investment (Peyrard and Peyrard, 2001).

$$(BN_t) = \frac{R_t - C_{vt}}{(1+i)^t} \qquad (27)$$

$$(r_t) = C_0 - \sum_1^t BN_t \qquad (28)$$

Where :

$\left(C_0\right)$ = Construction costs of the biogas unit + installation costs of the biogas supply system;

(C_{vt})=Maintenance costs +Salary of the officer in charge of feeding the digester.

The payback period (PPI) is the period in which $r_n = 0$

When the period does not correspond exactly to a given year, it relies on extrapolation to determine the months and days equal. Moreover, for better appreciate the investment over the lifetime minimum operating unit of biogas, the net present value (VAN) was calculated (Lecaillon, 1989; Duhaut, 1991). It can make a decision on the acceptability of such a project. Indeed, when NPV is positive, the investment yields a greater profit than investing at the same rate of interest (Lecaillon, 1989). The minimum term of life of the structure is fixed at 10 years as the worst case scenario described by GTZ (1989). However, Nembrini and Kimaro (2006) estimates the life of a biogas plant built in brick clay to 30 years. Thus, VAN is calculated using the following formula:

$$VAN = -C_o + \sum_{t=1}^{10} Bn_t \times \frac{1}{(1+i)^t} \qquad (29)$$

According to the Bank of Central African States (BEAC), investments are made at an annual rate of 3.25% (BEAC, 2008).

III. RESULTATS AND DISCUSSION

3.1-Construction of biogas unit

After construction, it is possible to distinguish the main parts of a biogas plant are: the digester, the biogas tank and reservoirs pretreatment and discharge. In general, the figure 5 attests biogas unit can be built using the stones. The digester, the centerpiece of the system is almost completely buried. Conical base (Figure 6) enhances the resistance of the foundation and the wall. The biogas tank also allow a conical shape. Primarily this form to Prevent rain water stagnate on the roof of the Tank. As for the throat to water (Figure 6), its narrowness can better guide the movements of biogas tank that will be built. The digester tank pretreatment and the discharge were constructed in 40 days by three people. This reflects that the average construction volume of 0.7 m^3/d.

It appears from **Table 1** that from 21 tons of basalt stone in the rough (uncut stones), 680 pieces of 20x25 cm were cut and used for the construction of the digester. An average of 32 pieces per tonne of rough stones or 27 pieces/m^3 of digester. The number of rooms per cubic meter of digester is independent of the thickness of the wall. Moreover, the volume of other materials is proportional to it. Thus the stone wall 50cm thick requires 0.144 tonne of ciment per m^3 of the digester. This reflects an average of 2.88 kg ciment/m^3 digester / cm wall thickness. In general, 0.168 ton cement / m^3 of digester has built this stone biogas plant with a capacity of 25m^3. The quantities of stone carving, stone and sand are different and estimated at 0.88, 0.484 and 0.62 tonnes/m^3 digester respectively. However, the thickneess of the wall of the digester significantly affects the average quantities of materials.

The table 2 showed Inventory of materials used in the manufacture of biogas tank , the results showed that there is a need of 12m^2 black sheet for manufacturing the container body (part that goes into the water groove). This implies an average of 1.2 m^2 sheet/m^3 of the tank. As for the roof, the average is 1.4 m^2 of metal sheet / m^3. It was found that by following the standard procedure for construction of biogas tank, a loss of 21% of the metal sheet used for its roof is inevitable. This would explain also the difference between the average area covered by sheets above. Moreover, the average amount of rust inhibitor is applied in two layers of 0.22 kg/m^2 of the surface of the biogas tank. That of oil paint is 0.17 kg/m^2.

3.2-Temperature test

Data analysis of ambient temperatures and those of the digester used to trace the curves of their variations. They are illustrated in **Figure 7**. In general, it is clear from this figure that the temperature fluctuation knows more than the digester. Ambient temperatures taken at six o'clock in the morning ranged between 3.5 and 19.3 ° C. At the same time in the digester, they vary from 20.4 to 21.1 ° C and from 18.4 to 20.3 ° C respectively at 1.5 m and 0.3 m. At the noon (12 hours of the day), the minimum and maximum ambient temperatures are respectively 17.5 and 36.7 ° C. In the digester to 0.3 m, the minimum temperature is 19 ° C while the maximum temperature rises to 20.6 ° C. A 1.5 m, they are respectively 20.1 and 20.8 ° C. Finally, at 18 hours, the ambient temperatures vary from 8.8 to 18.8 ° C while in the digester, they fluctuate between 19 and 20.5 ° C at 0.3 m and 20.4 and 20.8 ° C at 1,5m. Thus, we find that environment, the thermal amplitude is greater than or equal to 10 ° C while it is below 2 ° C in the digester. Indeed, the ambient temperature is influenced by several factors including wind and solar radiation (Tabeaud, 2002). Permanent changes of these factors lead change of the instantaneous temperature of the atmosphere at a given location.

The ambient temperature is subject to constant fluctuations. Contrariwise, the temperature of the digester is not under the direct action of wind and incoming radiation. Which justifies its constancy and even fusion temperature curves at 0.3 m and A1, 5m. To this end, the temperature in each of the two points defined in the digester does not seem to be a function of time of day. In this context, Pahud (2002) observed that the temperature underground beyond 1m of the surface soil is more a function of temperature daily. It is rather variable depending on the season. Thus, the activity of anaerobic microorganisms mainly influenced by temperature would therefore be stable. Because according to Kuria and Maringa (2008), a daily fluctuation in temperature above 5 ° C causes a malfunction in the digester.

3.3-Biogas production test

The cumulative production of biogas is illustrated in Figure 8. It has a curve similar to a straight line. It has an average slope of 0.390. The slope indicates the hourly rate of biogas production in cubic meters. Thus, the average production of 0.390 m^3/h. The corresponding daily production of 9.36 m^3. It represents 52% of that expected during design. This reflects a situation of under production. However, two factors explain the low production. On the one hand, when the reservoir began to store biogas production, the substrate of the digester has lost almost all its potential in biogas. He spent three months in their collection and storage for two months in the digester without additional power. Following a shortage of manure, it could not be renewed. To this end, the production would be below the optimum. This seems to support the work of Demirbas (2008). That court found that 80-85% of the biogas production is achieved between the 15th and 18th day. And according to Kuria and Maringa (2008), the manure of beef is completely digested in the digester after 50 days. In turn, the substrate after two months in the digester would have emitted most of the biogas. Furthermore, the shape of the curve shows an almost constant production. Indeed, the digester was fed daily during the period of data collection. And again, it was found that the digester temperature is almost stable (Figure 7). These two fundamentals of the methane would have helped stabilize the activity of microorganisms.

3.4-Financial analysis of investment

3.4.1-Balance sheets for the construction of the biogas plant

Construction costs of parts of a biogas plant are summarized in **Table 3.** The result shows that the digester and the biogas tank are essential parts of a biogas plant in terms of cost. They represent respectively 64.4% and 30.4% of total costs. These results differt from a similar assessment made by Kuria and Maringa (2008). According to them, the cost of building a digester of 14.7 m^3 is exactly 62.9% of total costs. As for the biogas tank of 7.5 m^3, the cost is 31.3% of total costs. Compared to the digester, moreover, the average total cost of construction of the biogas plant using local materials is 50.498FCFA / m^3. The latter could be substantially higher if the cost of expertise had been taken into account. In considering the latter to 400.000FCFA, the average cost would then 66.498FCFA/m^3. However, this result remains very competitive. Indeed, the average cost of a biogas plant built in 10m^3 of clay brick in Côte d'Ivoire is 150,000 FCFA/m^3 (N'goran, 2006) or 126% more expensive. And in Yemen, Hammad *et al.* (1999) report that the construction cost of a unit of 90m^3 is 74700FCFA/m^3. The use of local materials is the main reason for the substantial decrease in the average cost. Moreover, the supply of biogas has cost 146,450 FCFA FCFA wheteher 1627.23/m, Thus it represents 12% of the total construction cost of the biogas plant. This brings the total amount of investment to 1.408.905FCFA.

3.4.1-Payback period of investment and net present value

Variable costs related to the operation of the biogas plant is estimated at 205000FCFA year. Every four years of operation, it is expected that the biogas tank is renewed. To this end, the payback period and net present value calculated for assessing investment are summarized in Table 4. In a situation of under production, we see that PPI is about a third of the minimum operating unit of biogas. This means that this investment generates enough financial interest justifying its implementation. This payback period confirms the results from the work of Nembrini and Kimaro (2006) Rwanda. According to them, expenditures for the construction of a 600m3 digesters may be collected within two to three years. Moreover, it is clear from Table 4 that optimal production situation, the investment could be recovered in one year four months. Which invalidates the results of Hammad et al. (1999) who are 20 years in the PPI. However, this disparity around the payback period can be explained partly by the type of materials and costs that vary from one region to another. On the other hand, the costs of energy substituted by biogas on which revenues also vary. Therefore, the financial profitability of a biogas plant depends on the availability of other energy resources to substitute.

When the substrate used requires presorting such as household wastes, the recovery time would probably be longer. Indeed, the sorting of waste is costly. On the other side, PPI could be shorter in regions where sources of cooking energy are becoming scarcer and therefore expensive. For example, in the region of the Far-north of Cameroon over 99% of the population use firewood as a source of energy for cooking (INS, 2004). Unfortunately, this threatened resource scarcity is becoming increasingly rare. In such an environment, the biogas plant of this size in a state of optimal production would replace 32.85 tons of wood per year. And estimating the price of one kg of wood to 100 FCFA annual revenues amount to 3 285 000 CFA francs. Taking account of the discount factor and a variable cost per year, the net present value of this recipe would be 2 983 051 FCFA. Therefore, PPI is 6 months.

However, PPI does not allow a clear view of the long-term ability of an investment to raise revenue. Thus, this analysis does not provide information on the likely revenue that can generate the operation of the biogas beyond the PPI. Lecaillon (1989) also notes that these deficiencies present this assessment tool. To this end, the discount value (NPV) can raise this limit. It appears from Table 4 that all NPV are positive. This indicates that there is more profit to invest in the production of biogas to place the funds on capital markets at the rate recommended by the BEAC. In other words, in situations of under production, biogas converted butanes 2 124 914 CFA francs more than the interest that could generate the same amount of money placed on the capital market.

The financial evaluation of biogas unit can not appreciate some aspects of economic exploitation. For example, the use of biogas is involved in the fight against climate change by minimizing the emission of methane and deforestation. In addition, the use of biogas as compared to the firewood would reduce the causes of deaths caused by polluted indoor air. Finally, possession of a biogas plant has a cordless cooking energy. All these elements provide a level of satisfaction that the price could be enough to justify the investment. Moreover, Agu *et al*. (2000) finds that the environmental benefits justify only investments of a large number of biogas projects.

IV. CONCLUSION

A biogas plant can be constructed using stones. Its volume is 25m^3, while its diameter and height are respectively 3.2 m and 3.1 m. From beef manure, the digester can provide 18m^3 of biogas per day to feed 35 students. During the production of biogas tank following the standard procedure, there is a loss of 21% of the sheet metal used for roofing. The use of sheet metal 8/10 recovered from metal drums is not appropriate. In the digester, the temperature test shows that it is stable and favorable to the anaerobic zone in psychrophilic. On average, it varies from 19.71 ° to 20.55 ° C respectively between 0.3 m and 1.5 m from the base of the digester. The diurnal variation is less than 2 ° C. The financial evaluation of biogas unit constructed shows that the cost of work is about 1.300.000FCFA, whether an average cost of the digester 52.000CFA/m^3. This reflects the cost substantially lower interest related to the use of local materials (basalt stones) for the construction of a digester. Taking into account the cost of water supply network, the total amount invested is almost 1.500.000FCFA. Situation in a production of 0.390 m^3 / h of biogas as a period of sub operations, the payback of this investment is three years. The net present value for a minimum lifetime of 10 years is about 2.000.000 FCFA. Moreover, investment can be recovered in one year four months when production is optimal. In this case, the net present value for the minimum term of life mentioned above is almost 7.300.000FCFA.

REFERENCES

[1]. Aburas R., Hammad. M. A., Hiary S. E., Qousous S., Abu-Reesh I., 1995. Construction and operation of a demonstration biogas plant, problems and prospects. Energy Convers. Mgmr, 37: 611-614.

[2]. Agence de l'Environnement et de la Maîtrise d'Energie (ADEME), 2006. La méthanisation à la ferme. Site web : http://www2.ademe.fr

[3]. Agu S., Bonnefoy A., Devaux L, Mouilleron T., Touret H., 2000. Agriculture et effet de serre : adaptation des pratiques agricoles, alternatives énergétiques. Rapport scientifique, Ecole Supérieure d'Agriculture 55 rue Rabelais BP 748 49007 ANGERS CEDEX 01, France, 95p.

[4]. Banque des Etats de l'Afrique Centrale (BEAC), 2008. Evolution du marché des capitaux. Bulletin du marché monétaire, 172 : 1-84

[5]. Blondin P., Fokwa D., Embogo D., 1993. Guide de Tacheron. SOPECAM, Yaoundé, Cameroun, 211p.

[6]. Breuil F., 2007. Tirer le meilleur parti possible du méthane.

[7]. Site web : http://www.usinfo.state.gov

[8]. Caussade, 2006. Production de biogaz. Site web: http://www.caussade-semences.com/File/BIOGAZ.pdf, 20p.

[9]. Charon P., 1986. Béton armé suivant règles BAEL 83 : théorie et pratique. Eyrolles, boulevard Saint Germain, Paris, France, pp. 444-461.

[10]. Demirbas A., 2008. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Conversion and Management, 49: 2106-2116.

[11]. Diop C. A., 1985. La science, la technique et le développement de l'Afrique- l'Afrique et son avenir. ANKH, 14 : 163-167. Site web : http://www.ankhonline.com

[12]. Duhaut M., 1991. Mathématique appliquée à la gestion de l'entreprise. Tome1. Techniplus, Paris, France, pp. 87-110.

[13]. Food and Agriculture Organization of the United Nation (FAO), 1984. Biogas: What it is; how it is made; how to use it. Better Farming Series 31: 1-5.

[14]. Gérat L., 2008. Un virage énergétique à négocier. La Recherche, Cahier spécial 417 : 6-9.

[15]. Gesellschaft für Technische Zusammenarbeit (GTZ), 1989. Biogas plants in animal husbandry. Deutsches Zentrum für Entwicklungstechnologien-GATE.

[16]. Site web: http://localhost/cgi-bin/gw, 153p.
[17]. Gesellschaft für Technische Zusammenarbeit (GTZ), 1988. Biogas plants. Deutsches Zentrum für Entwicklungstechnologien-GATE, Eschborn0, Germany, 77p.
[18]. Greenfacts, 2006. Consensus Scientifique sur le Changement Climatique.
[19]. Site web: www.greenfacts.org ,
[20]. Hammad M., Badarneh D., Tahboub K., 1999. Evaluating variable organic waste to produce methane. Energy conversion and Management, 40: 1463-1475.
[21]. Igoud S., 2002. Le biogaz: une solution énergétique viable. Bulletin des énergies renouvelables. Site web : www.cder.edu.dz
[22]. Institut National de la Statistique (INS), 2004. Annuaire statistique du Cameroun. Deuxième partie : population et affaires sociales. Institut National de la Statistique, Yaoundé, Cameroun, pp. 31-272.
[23]. Institute of Science in Society (ISIS), 2006. Energie renouvelable; le biogas en chine. Communiqué de presse de l'ISIS. Site web: http://www.isis.org.uk/BiogasChina.php , 23p
[24]. Kuria J., Maringa M., 2008. Developing simple procedures for selecting, sizing, scheduling of materials and costing of small bio-gas units. International Journal for Service Learning in Engineering, 3: 9-40.
[25]. Lecaillon J., 1989. Analyse microéconomique : les entreprises ; production et prix. Editions Cujas, Paris, France, pp. 69-75.
[26]. N'goran C., 2005. Communautés locales et gestion durable des énergies en Afrique ; *Cas de la Côte d'Ivoire*. Technologies appropriées et actions participatives face aux défis écologiques mondiaux. SGP/UNOPS/PUND, Abidjan, Côte d'Ivoire, 53p.
[27]. Pahud D., 2002. Geothermal energy and heat storage. Site web: www.isaac.supsi.ch, 133p.
[28]. Peyrard J., Peyrard M., 2001. Dictionnaire de finance. Vuibert, Paris, France, pp. 86-257.
[29]. Ranald V. G., 1988. Mécanique des fluides et hydraulique : cours et problèmes. Imprimerie Louis Jean, France, 272p.
[30]. Renewable Energy Policy Network (REN21), 2005. Energy for Development: The potential role of renewable energy in meeting the millennium development goals. Worldwatch Institute, Washington, DC. 46p.
[31]. Sanglerat G., Olivari G., Cambou B., 1983. Problème pratique des mécaniques des sols et des fondations : calcul du soutènement et des fondations, stabilités des pentes. Bordas, Paris, France, 272p.
[32]. Tabeaud M., 2002. La climatologie générale. Europe média duplication S.A, Lassay-les-53110 Châteaux, France, 95p.
[33]. Tippayawong N., Promwungkwa A., Rerkkriangkrai P., 2007. Long-term operation of a small biogas/diesel dual-fuel engine for on-farm electricity generation. Biosystems Engineering, 98: 26-32

Table 1: Inventory of building materials from the digester, pretreatment discharge tank

Description	Digester	Pretreatment tank	Discharge tank	Total Quantity
carved Basalt stone (tonne)	21	0	1	22
Carved stone (pieces 20x25cm)	680	0	96	776
Various stones (tone)	14	0.5	1	15.5
Sand (tone)	10.5	0.9	0.7	12.1
Gravel (tone)	1.5	0.01	0.020	1.53
Cement (tone)	3.975	0.25	0.20	4.2

Table 2: Inventory of materials used in the manufacture of biogas tank

Designation	Quantity
Black sheet 15/10 (m2)	12
Sheet 8 / 10 (m2)	14,4
Angle 35x35 (m)	12
GI pipe 60 (m)	2
Oil painting (kg)	8
Rust (kg)	10
Mastic (kg)	1
ISOPON P38 (kg)	5
Thinner (liter)	6

Table 3: Balance sheet of construction of the digester and biogas tanks, pretreatment and discharge.

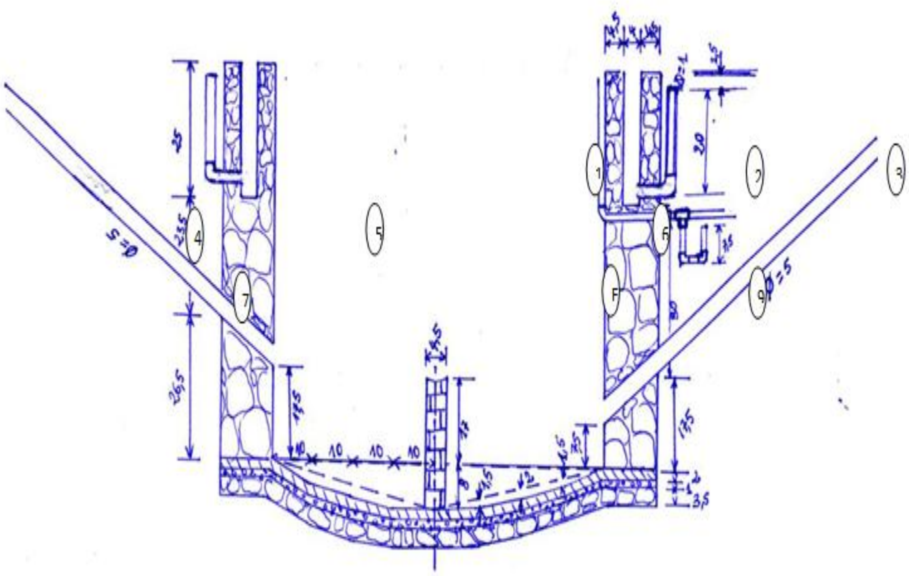
Designation	Volume (m^3)	Financial cost (FCFA)	Average cost (FCFA)
Digester	25	813.050	32.522
Pretreatment tank	1.23	33.785	27.467
Discharge tank	2	31. 920	15.950
Gas tank	10,8	383.700	38.994

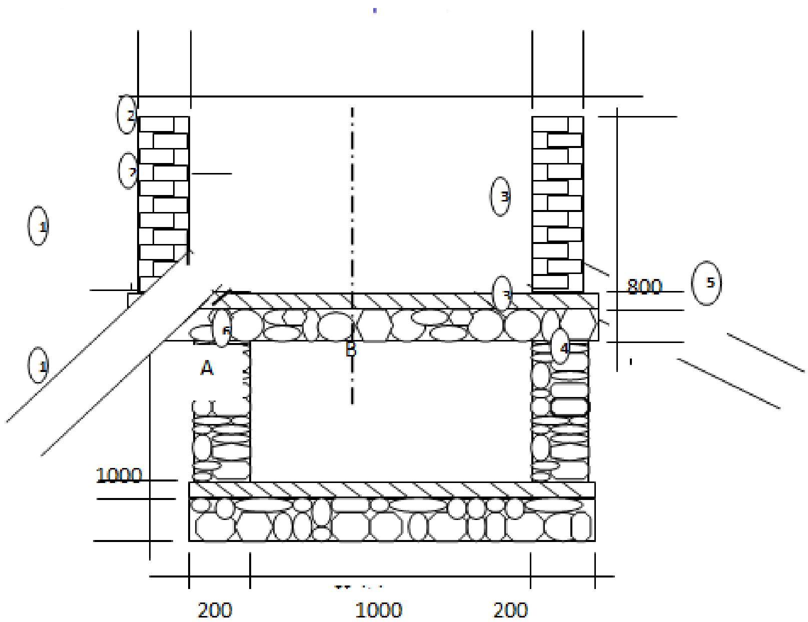
Total cost (FCFA)		**1.262.455**	
Average total cost (FCFA/ m^3 of digester)			**50.498**

Table4: Payback period of investment (PPI) and net present value (NPV)

Elements of assessment	Status Under Production (0.390 m^3/h)	Optimal production (0.75 m^3/h)
PPI	3years	1year and 4 months
NPV	2.073.114	7.269.645

Figure 1: Modified cylindrical digester throated water: external wall, internal wall, throat, water, wall partition, biogas intake pipe, water level regulator in the throat, feed pipe from the digester, water trap





fgure 2: Pretreatment tanks and discharge. (A) pretreatment tank. It is above ground. (B) reservoir discharge. Supply pipe, cinder-block wall stuffed concrete slab, Hérissonage, Conduct Discharge, Stone Wall

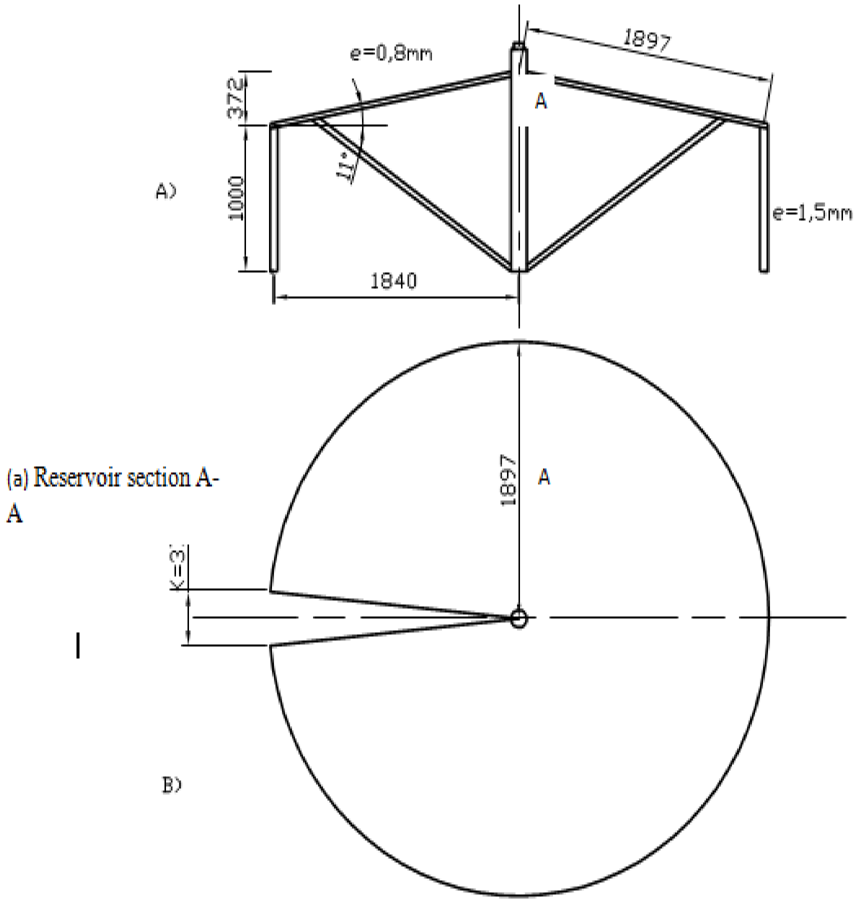


Figure 4: Some stages of excavation: (a) area to be excavated, (b) execution of works, (c) end of excavation

Figure 5: Different step of the foundation: (a) and (b)-transformation of the base, (c)- ruffle the strike in the conical shape, (d)- layout of the floor slab.

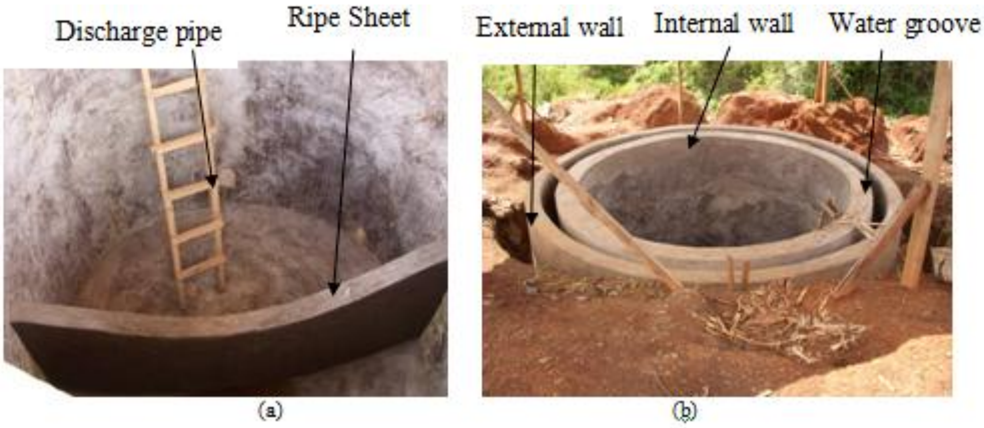


Figure 6: (a) inside of the digester (b) outside of the digester

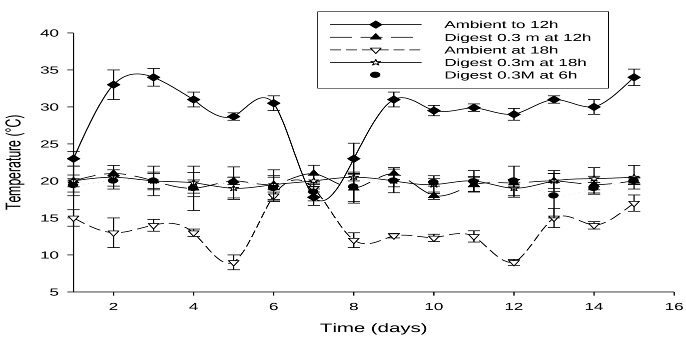


Figure 7: Variation of ambient temperature and the temperature of the digester to 0.3 m from the base

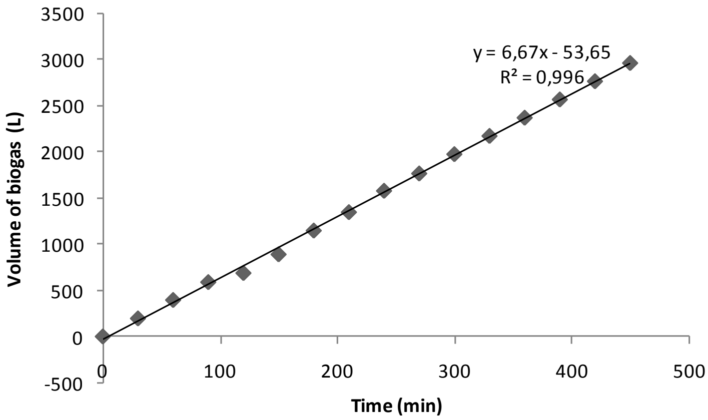


Figure 8: Biogas production curve