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# Influence of Climate Temperature on the Valorization of Dung-Wastewater Slaughterhouse Biogas in Two Regions: In Chad and Senegal

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## Abstract

In this work, we have produced biogas by co-digestion of cow dung and slaughterhouse wastewater under different climate temperatures in two countries: N'Djamena in Chad, a country of Central Africa and Dakar in Senegal, a country of West Africa. In a first approach, we put the cow dung in cans of 1.5 L, hermetically closed. The goal was to know how long you could produce biogas. Then we built a bio-digester to produce biogas for cooking. Each bio-digester was exposed to receive solar heat that varied between 27˚C to 41˚C in Chad and between 24˚C to 30˚C in Senegal. Influenced by the high temperature and a minimum residence time, the experiments showed that the N'Djamena test produced biogas more quickly than the Dakar test which, on the contrary, had a low temperature and a long residence time. The production of biogas began at the end of seven days with flammability on the twenty-first day for the bio-digester in Chad and after twenty-seven days with a flammability on the thirty-sixth day for the bio-digester of Senegal. The different digestates were valorised in fertilizers, bricks and green coal. Our research aims to meet the living conditions of the rural world specifically for women by reducing their work and thus allowing them to have more time to self-educate and educate their children.

**Keywords**

Co-Digestion, Climate Temperature, Cow Dung, Slaughterhouse Wastewater, Biogas, Digestat, Rural World, Self-Education

## 1. Introduction

Anaerobic digestion is a versatile biotechnology for converting organic waste into valuable biogas. One of the most profitable aspects of anaerobic digestion of manure allows both the production of bioenergy and the production of nutrient-rich soil amendment [1], because the presence of ammonia in the digestate is interesting for the production of ammonium sulphate, a fertilizer that promotes plant growth [2], reduction of greenhouse gas emissions and odor control [3] [4], it is therefore consistent with agricultural practices [5] [6] and the environment as well as the adaptation to climate change of different crops that can not only feed a whole population but contribute significantly to the production of biomass very favorable to biogas [7] [8]. This anaerobic digestion must take place in an enclosure called anaerobic bioreactor or fermentor consisting of a closed tank, airtight and preferably thermally insulated from the outside, in which different bacterial species take turns to degrade the organic waste compounds, or effluents and produce biogas [9] [10], mainly composed of methane but also carbon dioxide [11], while halving the level of organic matter represented by biodegradable by-products [12] [13]. This oxygen-free medium must respect several parameters in order to lead to a different optimized and controlled reaction to produce biogas that can be recovered in various forms [14] [15]. Among these parameters, temperature is one of the most sensitive elements to good biogas production. Our study focuses on the possibility of producing biogas under the influence of climate temperature in two regions of Africa with a completely different climate.

The study conducted by [16] examined the temperature dependence of $CH_4$ emissions from pre-storage of animal manure prior to anaerobic digestion at 15˚C, 20˚C, 25˚C and 30˚C using anaerobic digesters in the laboratory. Research has shown that with minimal temperature and adding waste into the digester $CH_4$ emissions can be reduced, but with high storage temperature these emissions are increased. Thus, in mesophilic or near-mesophilic temperature conditions, cow dung has a high biogas production potential [17]. The environmental benefits of using digesters for low-cost biogas and low-cost digestate production in small-scale farms would significantly reduce (up to 80%) the potential environmental impacts associated with handling stored and non-upgraded manure, the use of fuel liquefied petroleum gas (LPG) used for cooking and also synthetic fertilizer used in crops [18]. The aim of this research is to respond, on the one hand, to the low energy supply rate of rural populations in Chad and, on the other hand, propose an easy digesters assembly technique. The low energy supply rate in developing countries, which is also a major handicap for their socio-economic and environmental development [19], is attracting increasing interest. Several countries in Asia and Africa, including China, India, Nepal, Bangladesh, Cambodia, Vietnam, Kenya, Rwanda, Tanzania, Burkina Faso and Senegal are launching massive campaigns to promote biogas technology [20] [21]. Chad for its part remains by far the technology and/or the applicability of this resource. Faced with a growing population, the consumption of biogas energy can contribute to the problem of women's poverty, especially in rural areas, where people prefer to cook by cutting trees [22]. In addition, the energy use of wood has a negative impact on women's health because of the smoke released during cooking. The use of biogas helps to significantly reduce the time and labor of women, which could be used for other productive purposes, and to improve their health [23]. Our case study is based on animal waste mainly cow dung but could also consider any other type of livestock waste or other with a good methanizable potential. Thus, Chad is a country of breeding par excellence, however this breeding generates an impressive quantity of waste but unfortunately the techniques and the knowledge of the valorization of the latter remain poorly known. Until May 3, 2018 The Chadian herd counted 113,560,000 head of cattle and 34.6 million head of poultry. The "livestock" group consists essentially of ruminants such as goats (32.5%), sheep (28.2%), cattle (26.5%) and camels (6.8%). Poultry was dominated by chicken farming with 26.6 million head, or 77% of the total. Other poultry are ducks, geese, guinea fowl and pigeons. These figures put Chad in third place in Africa in terms of livestock and could thus become the main engine of the Chadian economy. Its modernization would be a great breeding ground for rural employment and an important source of diversification of processing activities of livestock by-products [24]. Chad, although having a significant energy potential, it is difficult to obtain precise data on the use or application of solar energy and biogas, only a society uses its waste in electricity. Of the Sarh Sugar Corporation using sugar cane bagasse to convert this biomass into electrical energy, wood is the main source of cooking energy used by 75% of households in urban areas [25]. In Senegal, livestock is an important part of its economy. Like agriculture, it is one of the main income-generating and employment-generating activities of rural populations [26]. The biogas initiative launched by the Government of Senegal, in collaboration with some international organizations, was to develop bio-digesters as commercially viable products to reduce poverty and improve health by reducing the pollution associated with firewood, reducing deforestation and producing digestate as an alternative to inorganic fertilizers in rural areas. The Senegalese government's biogas program, which targeted the installation of 8000 digesters between 2009 and 2013, has not achieved its objectives, with fewer than 600 units built. One study found that the development of clean cooking fuels in Senegal is hampered by poorly designed and poorly implemented government policies and by the structural and endemic poverty of rural people, particularly farmers who are mainly involved in agriculture and agriculture. Breeding. She proposes to solve the problem by proposing a new paradigm combining livestock breeding, income generation and market-oriented domestic biogas production to provide farmers with clean cooking energy through biogas digesters [27].

## 2. Materials and Method

### 2.1. Materials and Substrate

During our work we used a substrate that was cow dung taken directly to the local cattle market in N'Djamena and Dakar and waste water from slaughterhouses in different countries. We present a photograph of the substrate in Figure 1.

The mounting equipment consisted of: A number 13 car air chamber; a 30l can serving as a digester; a garden hose; a fitting adapted to the pipe; two (2) T-fittings; two (2) single fittings; two (2) brass nipple; a sealing ring; a burner or stove; a 6 mm gas pipe; a tap and safety valves.

After assembly we have this.

Figure 2 shows the diagram of the bio-digester used for the production of biogas with these different components.

(a) (b) (c)

Figure 1. Substrate photography. (a) Cow dung N'Djamena; (b) slaughterhouse waste (blood and gut content); (c) Cow dung Dakar.

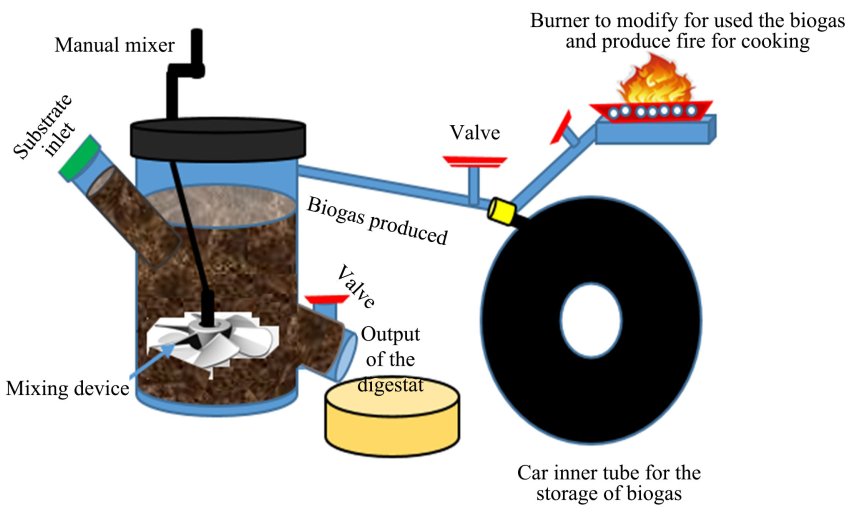


Figure 2. Diagram of the bio-digester.

### 2.2. Method

The assembly of bio-digesters followed the method described by [28]. Once completed, we filled the water digester for safety reasons related to any escape. The lack of flow allowed us to implement our production. The water is then removed from the digester tank by the digestate discharge part. For the implementation of the introduction of the substrate and the production of biogas, the method used consists in producing an intermediate sample which will be used as a base for the production of biogas, the volume/mass of which is conditioned by the type of analysis to achieve. Then we calculated the density.

The formula for calculating the density is as follows:

Density = (Sample mass − Curb weight containing)/Volume of the weighed substrate.

Units:

- Mass of the sample: in kilograms.
- Mass of the container: in kilograms.
- Volume of the substrate: in liter.

Cow dung is weighed for a specific mass. Slaughterhouse waste water is added and the mixture is mixed in a vat to allow the dung and water to form a homogeneous mixture. For our use as a 30l digester, we took a mass of cow dung representing less than 1/3 of the summer and a volume more than 2.5/3 of water. The whole of our mixture is evaluated to 28l in ours was of a capacity of 30l. A water content such as the weight of water represents 90% of the weight of semi-solid raw materials [29]. The upper part was thus left for the gaseous cloud that should pass through the pipe connecting the digester and the air chamber used for storing biogas. Once weighed and mixed, we introduce the substrate into our digester by the part dedicated to this action. For this part we have adopted the methodology of written by [30] and [31]. The volume of our system being known, we made a calculation approach previously described by [32] but our results according to the experience made in Chad are different from that of Senegal. The pH was measured initially on the substrate before introduction and at the outlet of the digestate with a pH-meter of the type "Preciva Pen type PHmeter" Model: PH3200001. The temperature is measured daily with a thermometer type "Infrared thermometer −50˚C - 400˚C".

## 3. Result and Discussion

### 3.1. Measurement of the Ambient Temperature

Each bio-digester was exposed to receive solar heat that varied between 27˚C to 41˚C in Chad and between 24˚C to 30˚C in Senegal.

#### 3.1.1. Case of Chad

The experiments were done in both countries in hot season, so for Chad the very hot season lasts 2.3 months, from March 18th to May 27th, with a maximum average daily temperature above 39˚C. The hottest day of the year is April 15, with a maximum average temperature of 41˚C and a minimum temperature of 26˚C

[33] In terms of measurements, work began from March 21, 2016 to May 20 2016. We present the measurements of the ambient temperature as a function of the retention time in Chad in **Figure 3**.

Chad is in the upper sun zone of Africa. The number of hours of sunshine per year varies from 2850 hours in the south to 3750 hours in the north of the country. The intensity of global radiation varies on average from 4.5 to 6.5 $kWh/m^2/d$. [25] the production temperature of the biogas for the experiment made in Chad is close to that of [34] which for their part had a co-digestion between cow dung and water hyacinth.

### 3.1.2. Case of Senegal

In Dakar, the maximum average is 24˚C from January to March and between 25˚C and 27˚C in April, May and December. From June to October, temperatures reach 30˚C [35]. We started our work from June 2nd to August 2nd 2017. **Figure 4** shows the measurements of the ambient temperature as a function of the retentio time of the biogas production in the Dakar digester in Senegal.

The production temperature of our biogas for the experiment in Senegal is close to that of [36] who had rather co-digested cow dung with a corn husk for the production of biogas at the laboratory scale. The curves in both cases are about the same as those of [34].

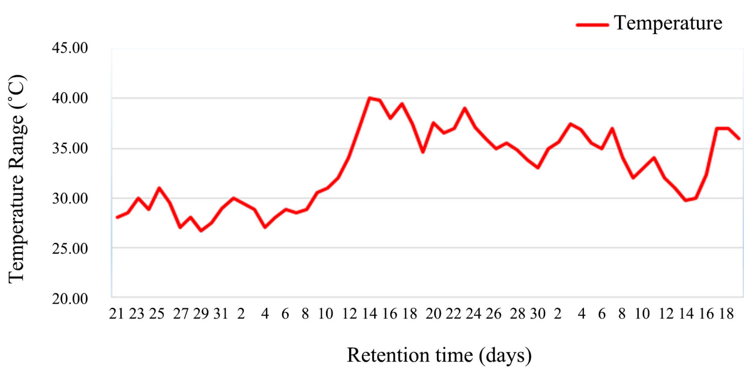


**Figure 3.** Temperature recorded for the production of biogas in Chad.

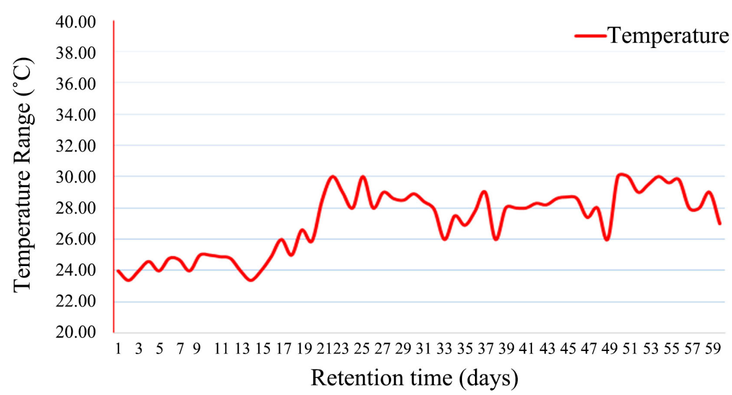


**Figure 4.** Temperature recorded for biogas production in Senegal.

### 3.2. Effects of Climate Temperature on Biogas Production in Rural Areas

The population in rural areas does not benefit from liquefied petroleum gases for cooking, they cut trees for firewood and coal.

This excessive cutting of trees causes deforestation and global warming. But most importantly makes women work harder and affects their health. To produce biogas, it is necessary to have a sufficient temperature capable of influencing the treated substrate and to convert the various stages of production of bio methane into biogas. The results of this article prove that with the ambient temperature of the climate we could produce biogas used for cooking. It is true that during hot weather the production of biogas is accelerated and during cold weather it can be delayed. However we are considering a solution in the cold time interval. Among other things, this solution would be to use sensors capable of transforming solar radiation into warmer temperature in the digesters, thus creating a serf process that prevents radiation and the heat entering from emerging.

A second case of solution would be to use solar radiation to create a stirring mechanism via a sensor that will provide energy capable of rotating a crank that will mix inside the digester. It has been shown that agitation is an important factor for biogas production. Monitoring the impact of agitation on the progress of the biogas production process is comparable to the effect of adding the inoculum from the point of view of the speed of the production process. The considerable effect of agitation in a digester is due to the fact that stirring allows the gas bubbles to be released from the deep layers, to maintain the homogeneity of the temperature at different levels and to avoid the consolidation of the crust on the surface of the digester. It promotes, in addition, the supply of bacteria in nutrients and their transport to fresh substrate, newly introduced. This positively influences the evolution of the productivity of the digester. A third example would be to use a solar water heater to either meter the digester in this water heated by solar radiation, or use this hot water to mix cow dung-slaughterhouse waste composed of blood, belly contents, fat and other. Finally one last solution would be to temporarily heat the digester with the biogas it produces. All these solutions can be the subject of different articles adapted to our context and for the simplicity of use in a rural area.

### 3.3. Time of Digestion

The time required for digestion in both cases was different. The production of biogas began at the end of seven days with flammability on day 21 for the bio-digester in Chad and after twenty-seven days with a flammability at day 36 for the bio-digester of Senegal. As for the experiment conducted in Chad, it is assumed that the digestion time was 21 days because the volume of the inner tube was observed, so the biogas was burned by period and from the twenty-first day onwards. On the fifth day, when the volume of the air chamber decreased as a result of the use of the biogas, the evacuation valve was opened to extract 80% of the contents and we added a fresh load of 80% in the digester. This process is repeated each weekend and Chad's bio-digester continues to produce a significant amount of biogas until the end of the experiments. For the bio-digester of Senegal the production began four weeks after the implementation of the bio-digester with a flammability noted on the thirty-sixth day. In this case, we assume that the normal digestion time took place in less than five weeks as in the case of [37]. Despite this, the quantity of biogas produced in the inner tube was lower than that of Chad.

### 3.4. PH Observation

The pH was determined in both cases at the beginning of the introduction of the substrate and at the end of each phase of biogas production on the digestate. We present the details of the different pH measured in **Table 1**.

PH is a very interesting indicator in the stabilization and the good progress of anaerobic digestion. There are several pH values ranging from 5.5 to 8.5, with an optimum around 7 - 8 [38] see 8.5 [39]. Since the anaerobic digestion processes are strongly influenced by pH, they can however take place optimally in the vicinity of neutral pH = 7 and between 6.5 and 7.5 giving a good yield for certain types of substrate and in better conditions. In our work, the results of the pH measured on the experiment in Chad are similar to the work of [40] and for the experiment carried out in Senegal the result is close to that of [41].

### 3.5. Biogas Production and Use for Cooking in Both Cases

In both cases of experience we used at the beginning of our activities a simple can of water of capacity of 1.5 L. These cans were considered digesters, so before having the ideal ratio for mounting our bio-digester, several experiments were made to find the right ratio that should allow us to use it in our 30 L digester and produce biogas within an acceptable time interval depending on the climate of the different countries of study. We assume that biogas produces in both cases to respect all the stages of the biological mechanisms of anaerobic digestion described by [42]. A photograph of the different uses of biogas for cooking is given in **Figure 5**. We did not measure the amount of biogas or these physical characteristics, however, the biogas was of necessary quality cooked throughout our work in different countries and this was our goal.

### 3.6. Valorization of the Digestate

One of our objectives was also to valorize the digests obtained during the different experiments and to use them for several purposes. Thus among the types of valorization of the digestate we have three axes:

The use of digestate to fertilize the soil [2] [43]: this valuation consisted of directly using the liquid digestate in cultivated plots by following the same watering process of the plants but by preparing the growing soil in advance with the liquid digestate (**Figure 6(a)**).

**Table 1.** pH monitoring.

| Observation p H | Zone | |
|---|---|---|
| | Chad Digester | Senegal Digester |
| pH entered on substrate | 7.2 ± 0.2 | 6.5 ± 0.05 |
| pH output on digestate | 8 ± 0.5 | 7.98 ± 0.02 |

(a) (b)

**Figure 5.** Photograph of stoves using fire from biogas for cooking. (a) Case of Chad; (b) Case of Senegal.

Valorization of digestate in crops

(a)

Valorization of digestate in the construction of sustainable bricks

(b)

Valorization of digestate in the manufacture of sustainable coal

(c)

**Figure 6.** Different types of recovery of digestate.

The second area of development is the use of the solid part of the digestate in sustainable brick making for house construction in rural areas where the introduction and use of cement is still difficult: the process consists of mixing the digestate solid with black clay and dirty end to mold all in a mold used for cement bricks: for this valuation, the characteristics of the brick are still under study and we have not for the moment build a wall with (**Figure 6(b)**).

For the third valorization and one of the most efficient in terms of ecology and respect for the environment, we manufactured an ecological coal. The solid digestate and a liquid part were used as a basis for mixing with several other types of household waste to dry. The whole is mixed under a given temperature and exposed to the sun. Once dry, it is still mixed with the digestate and covered under a sun shelter, once the moisture content is acceptable, they are put in a pressure mold to have a shape and exposed to the sun to dry and be ready to use (**Figure 6(c)**).

### 3.7. Future Outlook for Sustainable Development

In developing countries, and particularly in sub-Saharan Africa and South-East Asia, rural villages and remote areas often lack a direct link to power grids, locking them into a cycle of poverty and underdevelopment. More and more countries are nevertheless helping their fellow citizens to escape this energy trap by exploiting an unexpected and under-appreciated resource: animal dung. Poultry, pigs, sheep, cattle and other domestic animals generate about 85% of animal faecal waste. According to Elevage Mondial, turning this livestock manure into biogas offers a way to make a renewable fuel source available to more than one billion people for their home use, giving them access to sustainable, affordable and reliable energy. Chad and Senegal are both breeding countries par excellence. The graph shown in **Figure 7** gives a percentage of the animals that could be used for 90% of their excrement.

This approach has already been widely adopted in India and China. Between 2003 and 2013, China built 42 million small biogas plants (from chicken manure and livestock manure) that provide energy and light and heat, as well as many power plants in the country. Biogas, much larger, with a daily capacity of 18,000 to 60,000 kWh, by 2003, India had already installed nearly 3.4 million family-sized biogas reactors in several remote areas of the country, and by 2015 the number of family-size biogas plants across the country had risen. To four million, other countries in Asia and Africa are now exploring the use of biogas to develop household electricity production [44].

This figure (**Figure 8**) summarizes the importance of the use of biogas in a number of important and sustainable approaches. We propose this approach to contribute to the waste management system focused on biogas production of job creation and added value to the environmental protection mechanism in the rural world.

## 4. Conclusions

At the end of this work, we can say that the bio-digester, although a technique unknown in Chad remains, one of the best solutions for obtaining renewable energy from organic waste, which can be used as such without treatment or with treatment in the production of heat, for cooking and with treatment in gas engines and generators to produce electricity. In short, the goal of our work was to design an easy-to-use bio-digester adapted in rural areas to produce heat and prevent deforestation.

The anaerobic bioreactor makes it possible to transform volatile organic matter into energy, while preserving its fertilizing potential, both from the point of view of organic matter and mineral elements. It is therefore a way of energy recovery of products such as livestock manure and crop residues whose return to the ground is essential. If all organic wastes from the animal and plant world were recovered to exploit their fermentation gas that would be an important step for the environment. This combustible gas is obtained by the decomposition and fermentation of

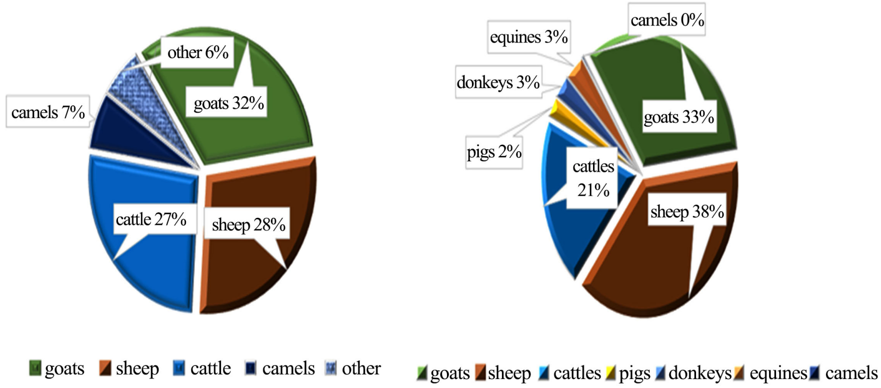


**Figure 7.** Percentage graph of the animals to which one could valorize 90% of their dung.

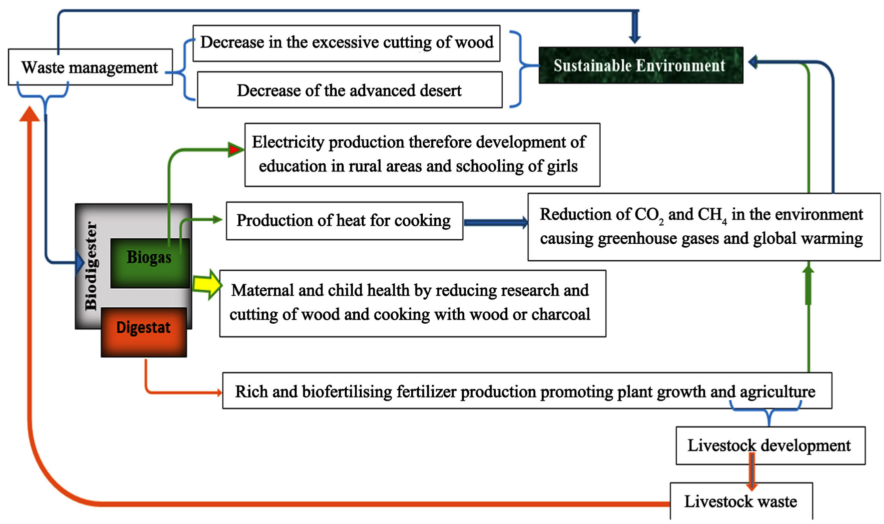


**Figure 8.** Solution approach in the waste management system focused on biogas production and sustainable development mechanism in the rural world.

organic matter in anaerobic (airless) medium. The gases released (mainly methane, $CH_4$) have an impact on the greenhouse effect 72 times greater than the same amount of $CO_2$.

A pile of manure left in the open will also produce methane. That is why it is doubly important to recover it, on the one hand to limit its impact on global warming and on the other hand to produce fuel in a country like Chad where the energy problem is a problem for all. Almost all the energy consumed is made up of traditional energies (95% in 2011). The country has the lowest per capita energy consumption in the world (0.16 toe) and 9 kWh of electricity (2011) [25]. Biogas technologies introduced at the household level aim to provide clean and sustainable energy, thus reducing the use of firewood [45] [46]. Senegal has almost achieved this policy.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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