Energy Recovery by Production of Electricity from Anaerobic Digestion of Organic Waste in the Saharan Environment

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ABSTRACT

Anaerobic digestion is a natural process of transforming organic matter into energy by methanogenic bacteria. This process is performed in the digesters in the absence of oxygen, they produce biogas composed mainly of methane (CH_4) which is a combustible natural gas we can used in everyday life. In this work, we produced biogas using a continuous digester with a capacity of 4m^3 and after the biogas purification; we used methane produced to run the generator to produce electricity. The results are very encouraging, where we have to produce electricity and cover the daily needs of the Algerian individual in electricity using 1m^3 of biogas from our digester.

I. Introduction

Municipal waste, assessed with a global production of 2.01 billion tonnes per year according to World Bank estimates in 2018 [1], cause damage to the environment and people. This catastrophic situation is accompanied by growing energy needs over 121,000 TWh per year in 2050 [2]. This production energy is based on fossil fuels and others: 32.5% petroleum, 27.9% coal, 23.4% natural gas, 4.4% nuclear and 11.0% renewable energies (hydroelectricity 6.8%, wind power 1.9%, biomass and geothermal energy 1.0%, solar 0.7%, agro-fuels 0.6%) [3].

In order to find a solution to these two global environmental problems, linked to the accumulation of municipal waste and the pollution of fossil fuels, digestion anaerobic is becoming an interesting prospect. This process uses organic waste as a raw material to produce biogas containing a significant proportion of methane (CH_4) which can be used as energy.

Biogas is a renewable energy source that can be used for the generation of heat and electricity or refined for use as a biofuel.

In Algeria, the first biodigestion projects were carried out towards the end of the years. thirty, under the leadership of two professors from the National School of Agriculture of Algiers (El Harrach), ISMAN and DUCELLIER, who filed a patent in 1938 in the United States of a system for producing a pulsating circulation in an apparatus containing products iberating gas [4]. This work was seen as the beginning of the mastery of production of biogas not only in Algeria but also throughout the world. In addition, they built the first digester. Based on their patent, many installations farms equipped with gas manure digesters and various equipment for upgrading
biogas have developed.

In 1949, an engine with 08 tanks of 40 m3 was developed. Provided with 260 tonnes of manure (05 cattle, 12 horses and 25 pigs), its production was nearly 30,000 m3 of biomethane per year until the 1960s, biogas was

developed in the kitchens of boarding schools (200 students), for the needs of the laboratory and 02 tractors. [5].
After the discovery of less expensive fuels at the end of the 1940s, activities in the field of bio anaerobic digestion have declined very rapidly. In Algeria, few Interest has been given to this technology despite the significant resources and applications achievements of the National Institute of Agronomy (INA El Harrach) and the Development Center Renewable Energies (CDER), thanks to the creation of two experimental plants in Bechar and Ben Aknoun, in 1986 and 2001, for the study of the production of biogas from of cow dung [6].
Since then, very few digesters have been developed. However, it should be noted that these years, the efforts of the Algerian government to develop this technology by modernizing the Ouled Fayet landfill, which was commissioned in 2011 The main objective of the project is to capture the gas from the landfill, which contains 50% methane (CH_4); the expected quantity of reduction in emissions is 83,000 T CO_2 equivalent / year [7].
In remote areas such as the Adrar region of southwestern Algerian Sahara, which lies distinguished by population groups populating villages called "Ksour", which are characterized by:

- Their large number (More than 300 ksar),
- Very long distance between them,
- Low population density.

These characteristics make it difficult for the population to connect to the electricity grid and expensive, and sometimes impossible with difficult to access desert terrain.
With this in mind, we are interested in producing electricity by recycling energy of organic waste (local substrates) in the Saharan environment and in particular those from the Adrar region: household waste and slaughterhouse waste using a continuous type digester.
Anaerobic digestion then becomes a promising prospect for solving the energy problem in these isolated areas, as well as a solution to the environmental problem caused by the accumulation of organic waste.

II. Research Method

II.1. The digester

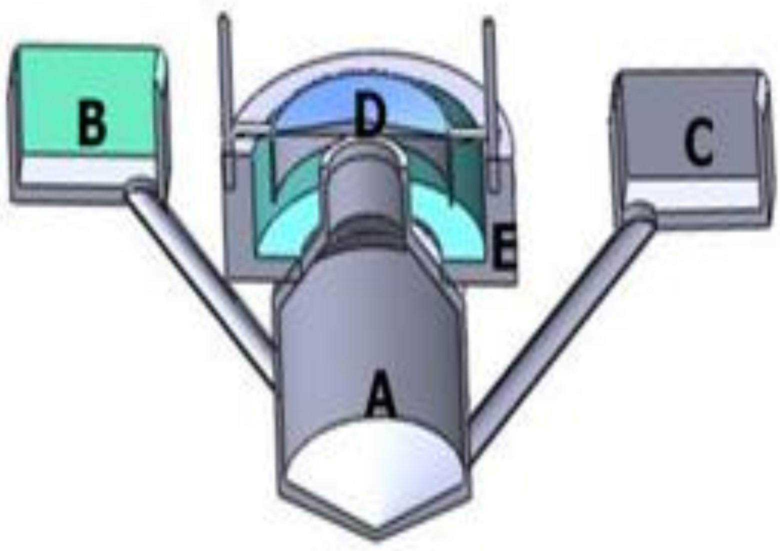
The experiment was carried out in a buried digester with a capacity of 4m3 at the level of the Renewable Energies Research Unit in the Saharan Environment (URER / MS) [8].
The construction steps in Table 1.

Table 1: The stages of construction of a digester with a capacity of 4m^3.

Step	Characterization	Photo
Realization of the pit of the pilot digester	3 meters deep; 5 meters wide; 4 meter of languor.	
Construction bottom of the tank digester	Lay on the bottom of the stone to a thickness of 10 cm. Place a layer of concrete to a thickness of 5 cm.	

Construction of the wall of the digestion tank.	The bricks are laid horizontally on the 15 cm thick side. The joints are well filled with cement mortar	
Construction of the digestate evacuation tank	The inclination of the pipe is 50 ° from the horizontal	
Substrate input tray construction	the angle formed with the horizontal is 53 °. a surface of 110 x125 cm	
Construction of the dome and dome hole	From the second row above the supply pipe, the deposited bricks are tilted so that the fourth row has a diameter of 50 cm	
Filling the pit.	the pit is filled with sand	

Construction of the gasometer tank	the diameter of the first circle is 300 cm, the second having a diameter of 250 cm.	
Gasometric bell	The sheet used for the manufacture of the bell is made of galvanized steel (ref. 15) The top of the bell has a hole to which a galvanized steel nipple is welded (ref. 15/21)	



A: Digestion tank; B: Feeder tray; C: Digesta evacuation tank; D: Gasometric bell; E: Gasometer basin
Figure 1. The different components of the underground digester.

II.2. The substrate

We fed the digester with 320 kg of slaughterhouse waste from the city of Adrar (southwest of Algeria) Characteristic of the substrates in table 2.

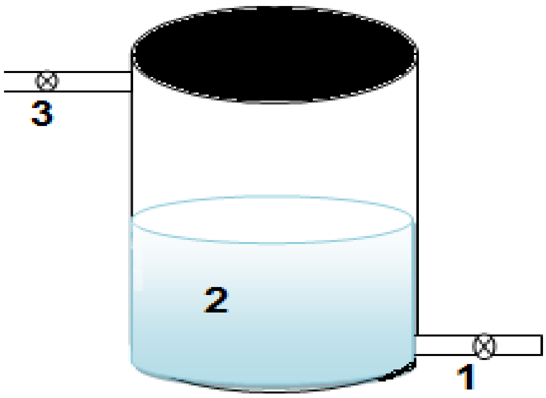
III. Methods used

Launch of an experiment on the anaerobic digestion of slaughterhouse waste in the underground digester of $4m^3$. During the 60 days of digestion we monitored the evolution of the following parameters: The pH was measured using a HANNA HI 8314 pH meter. On the other hand, the dry matter content, the organic matter content, the chemical oxygen demand (COD), the volatile fatty acids (VFAs) and total alkalinity were determined by the standard method [9]. In addition, analyses of the chemical oxygen demand (COD) were performed after centrifugation and filtration of the supernatant through a 0.45 µm filter [10].

III.1 Treatment of produced biogas

1) Removal of carbon dioxide

For the removal of carbon dioxide we used lime water which is a saturated solution of calcium hydroxide $Ca(OH)_2$, produced by mixing lime with water. Lime dissolves (weakly) in water and the resulting solution is lime water with a concentration of 10%.It changes color in the presence of carbon dioxide CO_2. The white precipitate thus formed is calcium carbonate $CaCO_3$.
The reaction is as follows: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$. (1)
Or, writing the species in ionic form: $Ca_2 + 2\ HO + CO_2 \rightarrow CaCO_3 + H_2O$ (2)
Our carbon dioxide filter is a sealed volume 150L barrel, with two shut-off valves at the top and bottom, we fill one third of the barrel with lime water and we pass the biogas that comes from digester from the bottom, the biogas is bubbled through the lime water solution at the top., figure 2.

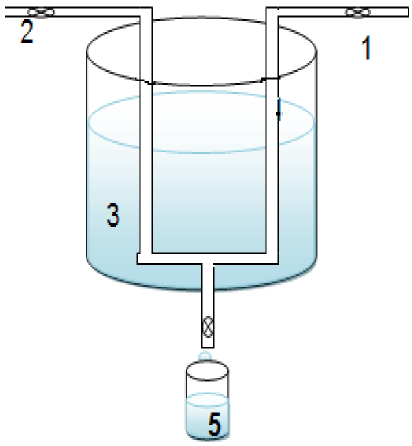


(1) Arrival of biogas; (2) lime water; (3) Exit biogas
Figure 2. Descriptive diagram CO_2 carbon dioxide filter.

2) Dehydration of biogas (Water trap)

Dehydration is a process of removing liquid water molecules or vapor contained in the gas, using physical or chemical means to avoid the following problems:
- Risk of pipe corrosion (especially in the presence of acid gases such as CO_2 and H_2S).
- Risk of solidification in cryogenic processes.
- Decrease in the calorific value of the gas.

We used a water trap (physical means) to liquefy the water vapor in the biogas, this trap is a plastic cylinder open from the top, at the lower part we made a hole in the center of the lower part, a U-shaped copper tube with a valve pass from the hole is installed in the carboy which is filled with ice water, the biogas enter hydrated entered from one side and exit dehydrated from the other side, the opening of the valve allows to recover the dehydration water Figure 3.



(1) Arrival of hydrated biogas; (2) Take out dehydrated biogas; (3) Ice water; (4) U shape copper tube; (5) Water recovery.

Figure 3. Descriptive diagram of a water trap.

3) Biogas desulphurization (H_2S filtering)

H_2S (hydrogen sulfide, hydrogen sulfide, hydrogen sulfide) is a poisonous and flammable gas with a typical rotten egg odor. Due to the toxicity of this substance, even inhaling low concentrations of hydrogen sulfide for a long time will prove to be dangerous, hence the importance of an efficient elimination of this substance, if present. in the biogas produced.

We have mounted a low H_2S filter on the oxidation of H_2S by iron according to the reaction:

$$2\ Fe^{3+} + H_2S \rightarrow 3\ Fe^{2+} + S + 2\ H^{+} \quad (3)$$

The filter is a plastic tube of 80cm in diameter closed on both sides with two valves, in the middle of the tube we put two layers of iron filings using a metal net, the biogas enter from the top sulphide and exit desulphurize at the bottom . Figure 4

(1) Exit desulfurized biogas; (2) Iron filings; (3) Arrival of sulfurized biogas

Figure 4. Descriptive diagram of the hydrogen sulfide (H2S) filter.

III.2 Electricity production

After treatment and measurement of biogas we used pure methane to start the generator in two tests with a load of 155wat, which represents the average consumption for the Algerian individual in electricity per hour according to the World Energy Bank [11]. To materialize this power in our experience we have chosen to use two 50wat lamps plus a 55wat lamp.

- In the first test: the generator started with town gas and with a load of 155wat, and we followed the power of the current by acquiring data for half an hour of time.

- In the second test: the generator starting with a load of 155wat. But this time the energy source is our biogas which is produced by the buried digester, and also we have followed the power of the current for half an hour of time. The final installation shown in photo 1.

(1) Digester; (2) CO2 filter; (3) Water trap; (4) H2S filter; (5) Air compressor;
(6) Regulator; (7) Gas meter; (8) Gas generator; (9) Load table;(10) Data acquisition.
Photo 1: Final installation.

IV. Results and discussions

IV.1 Characterization of the substrate used:

We fed the digester with 320 kg of slaughterhouse waste from the city of Adrar (southwestern Algeria), the characteristics of this waste are noted in the following table:

Table 2. Characteristics of the substrate before the launch of the experiment.

Setting	Unites	Value
pH		6,92
Humidity level	%	77
Dry matter rate	%	23
Organic matter rate	%	98
Chemical oxygen demand (COD)	Mg d'O_2/l	1523

IV.2 The pH

As shown in figure 5, the pH in the digestion was between 6.3 and 7.8, after the 15th day of the digestion the pH values remain in the range of 7-7.8 which is an ideal range for anaerobic digestion with good microbial activity and all phases of anaerobic digestion were expected.

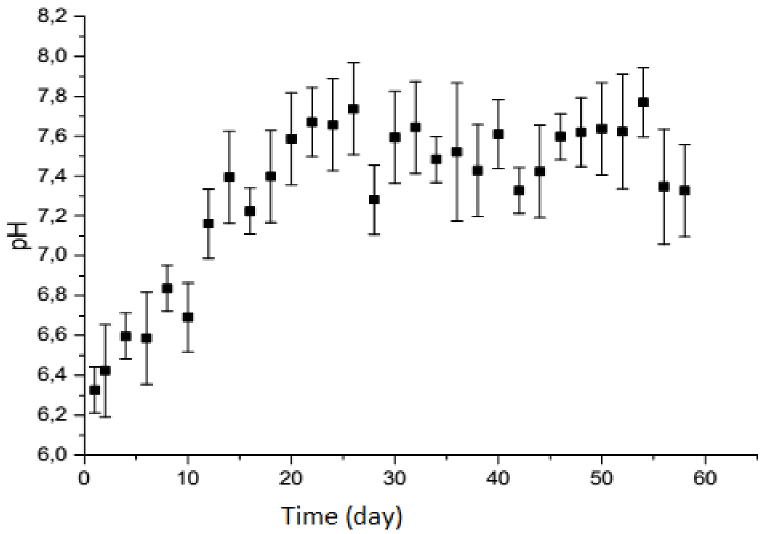


Figure 5: Evolution of pH as a function of time.

IV. 3 Chemical Oxygen Demand (COD):

Figure 6 shows the COD concentrations. COD values were elevated in the first 20 days, which was explained by the degradation of organic matter by bacteria in the acidification phase of hydrolysis and acetogenesis [12].
After 20 days, the date of the start of the anaerobic phase, we observed a gradual decrease in the COD concentration which was due to the transformation of the last stage products into biogas.

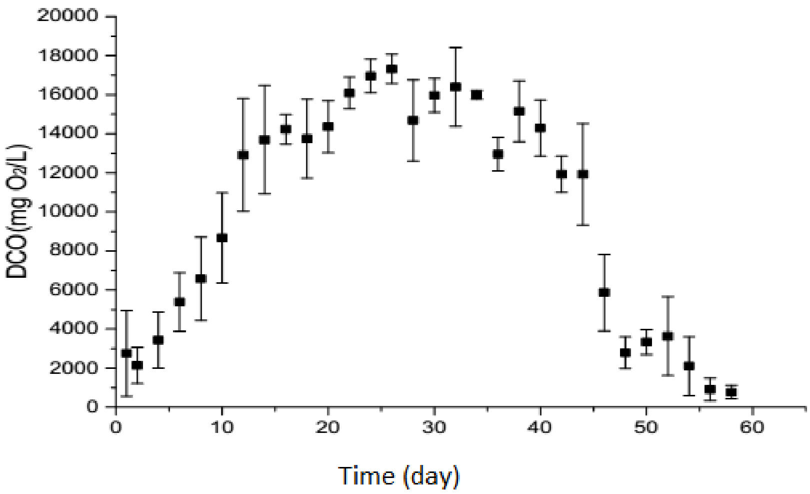


Figure 6: Evolution of the COD as a function of time.

IV.4 The volume of biogas :

The variation in biogas volume in Figure 7, an initial increase in biogas production, followed by a decrease, is typically observed in the anaerobic digestion process (a significant increase in pressure was recorded beyond the 17th day), the biogas produced becomes combustible from the 15th day (percentage of methane greater than 45%) from the 50th day, the volume reduced due to a total consumption of substrate. [13,14].

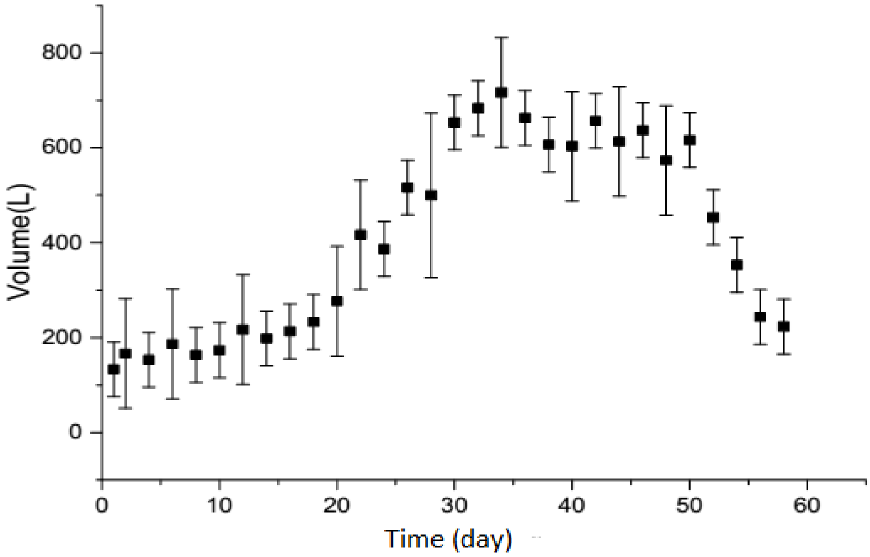


Figure 7. Variation in the volume of biogas.

IV.4 Monitoring the voltage of the electric current

The result of tracking recording of the voltage of the electric current in the two tests is shown in the following figure.

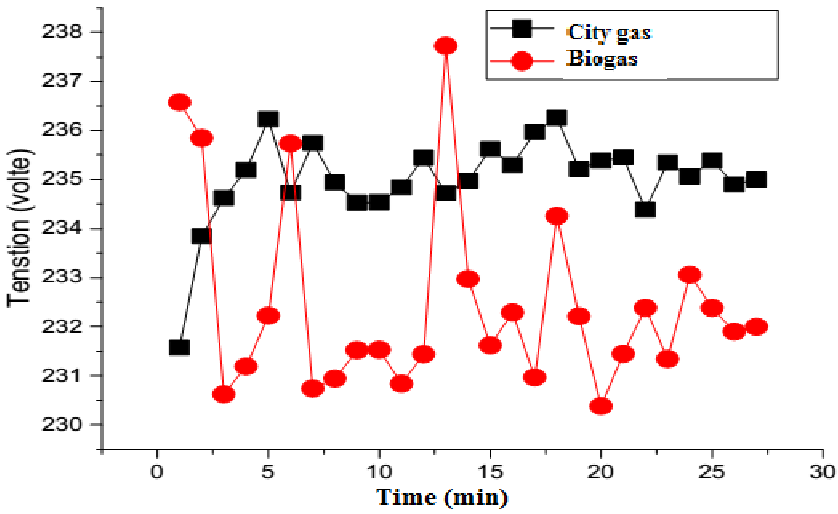


Figure 8. Recording of the voltage of the electric current with the town gas and our biogas.

Either with town gas or with biogas the generator gives a voltage varying between 230 and 238 volts, and more stable with town gas compared to what is produced by the biogas.
In both cases the voltage of the electric current remains within international standards or the voltage varies between 220 and 240V in most countries.

IV. 5 Monitoring of the intensity of the electric current

Recording the intensity of the electric current in the two tests is shown in the following figure.

Either with town gas or with biogas, the generator gives a varying current intensity between 0.650 and 0.680Ampère, and more stable with town gas compared to what is produced by biogas.

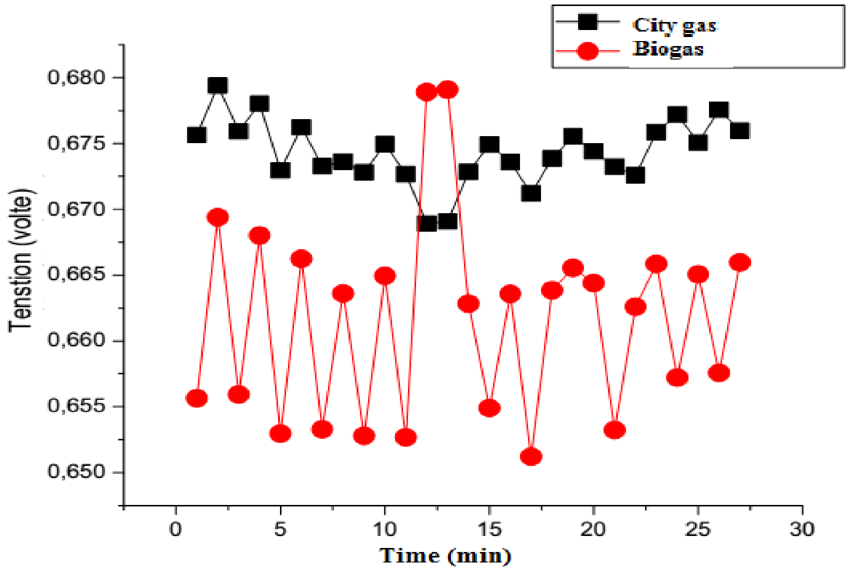


Figure 9. Recording of the Intensity of the electric current with town gas and our biogas.

IV.6 The power of the electric current

From the two records of voltage and current, the power of the electric current in the two tests is shown in figure 75. With town gas the recording of the power of the electric current is varied between 153 and 159 Wat, same remark for biogas, which explains why the generator ensures the power demanded by the load applied is 155 Wat. Figure 10.

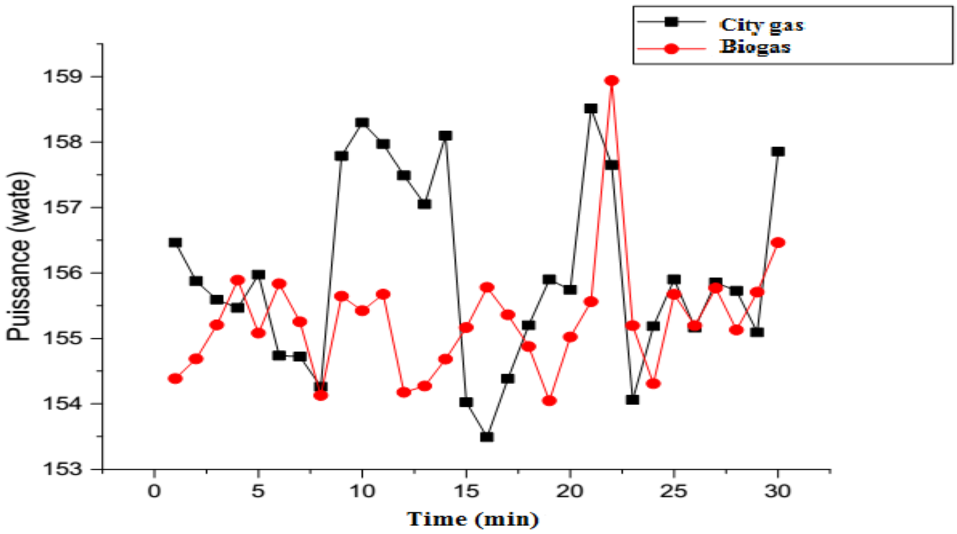


Figure 10. Power of the electric current with town gas and our biogas.

V. Conclusion

The results obtained showed that using the technique of anaerobic digestion we were able to recover this waste by producing 197.75 L / d of biogas, this gas can be used for cooking or to produce electricity.

The production of electricity by our generator has shown that in order to cover the daily needs of the Algerian individual in electricity we need a volume of 1008L of our biogas, this volume we can produce by the anaerobic digestion of 2kg of organic waste. in our digester.

At the end of this work, we can say that biogas can be a viable option as an alternative fuel for electric generators, especially in rural (Saharan) regions, where the relationship with the power grid is difficult and expensive, and we call for improved biogas purification methods for greater profitability in electricity.

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