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Energy recovery and Analysis of performance criteria of the energy potential of biomass for the production of electricity

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***Keywords*— Biogas, biomass, electricity, methanisation, Gaussian Mixture Model (GMM), DEEPLEARNING.**

***Abstract*— *This study focuses on the field of energy. Electricity production is an industrial sector that supplies consumers with electrical energy adapted to their needs. With current ecological and environmental requirements in the world, which wants to be more and more sustainable and non-polluting. The electricity production sector is seeking to exploit new sources of clean energy to align with today's sustainable context. The SDG 1. 7 for example is a leitmotif of the neo-producer of electricity in the 21st century who wants to guarantee access to reliable, sustainable and modern energy services for all at an affordable cost. So we made the choice of biomass in this work, as a source of primary, unlimited, non-polluting energy to produce, following its biochemical decomposition and fermentation, biogas which will be the raw material which will help us in the production of a electricity at a good price and accessible to large masses of the world population, two methods of analyzing energy performance criteria are developed in this work for a good selection of biomass, namely Gaussian Mixture Model (GMM) and DEEPLEARNING.*

[1] The Sustainable Development Goals give us the way forward to achieve a better and more sustainable future for all by 2030. Objectives set by the United Nations to which all countries adhere.

I. INTRODUCTION

All organic matter , whether of animal or plant origin, can be methanized to be transformed into biogas . At present, we most often use: agricultural waste (animal waste, crop residues such as straw, etc.), green waste (grass clippings, etc.), waste from the food industry (slaughterhouses , vineyards, dairies, etc.), station sludge. The biogas can be used for cooking energy, cogeneration for heat production or to produce electricity. Electricity is more interesting these days because we are in the phase of eliminating fossil sources and renewable and new energies such as biomass to electricity are more and more in vogue. Hence the role of the scientists that we are to provide more information on its real valuation in electricity by providing reference values to have a good yield in biogas and therefore a quantity of electricity produced on a permanent basis.

1.1. WHAT IS BIOGAS ?

Biogas is the gas produced by the fermentation of organic matter in the absence of oxygen. It is a combustible gas composed mainly of methane and carbon dioxide. The procedure for obtaining this organic gas without greenhouse effect is called "methanization".

1.2. What is Methanization ?

It is anaerobic fermentation, which is one of the processes that contributes to the degradation of dead organic matter, vegetable or animal, and their transformation into simple, gaseous and mineral elements. Thus the biological cycles are maintained where “nothing is lost, nothing is created, everything is transformed” [1].

Anaerobic digestion takes place in the absence of oxygen, which stabilizes organic matter by transforming it as completely as possible into gas (methane CH_4 (50 to 75%) and carbon dioxide CO_2 (25 to 50%)) [2]. It should be noted that it is microbial communities that are responsible for the decomposition of organic matter. The decomposition takes place in a closed container called a “digester”.

Anaerobic digestion ultimately results in two categories of the following elements: biogas and digestate.

Biogas is a mixture of methane (CH_4), carbon dioxide (CO_2) and water vapor (H_2O). Methane is the main constituent of natural gas. The digestate is the liquid residue containing the non-degraded materials.

II. PRODUCTION OF BIOGAS BY METHANATION ON THE DE BINZA-METEO SITE IN KINSHASA

In order to be able to identify the quantity necessary to be able to operate a generator and produce electricity thanks to the biogas collected, experimental studies have been carried out to have the quantities required for good exploitation of biomass in the production of electricity.

The experimental device consists of the following devices as shown in Figure 1. Below : A 3.5 m3 digester, a desiccant filter, a desulphurization filter, a gas meter, a 5 m3 PVC tarpaulin container and a generator 1.5 KW biogas.

It should be noted that concentrated products of the fermentation bacteria were added in the process in order to collect more of the biogas needed to operate a biogas generator.

Description and role of experimental equipment:

The digester: it is also called a biogas reactor, its role in this anaerobic tank is to digest the various organic materials placed there. To have a good yield, it will be necessary to add water to the digester, the quantities of which are given below in table 1.

filter : is a filtration system which aims to separate water from gaseous particles (biogas) from water (H_2O) by passing the product leaving the digester through a porous medium.

Desulfurization filter: safe elimination of hydrogen sulphide contained in biogas[3];

Storage container: waterproof PVC envelope intended to preserve the biogas produced;

generator : produces electricity with biogas used as fuel.

Fig.1: Experimental device (Named: MATITI ENERGY, Matiti which means plant or leaf in Lingala, vernacular language spoken in Kinshasa in DR Congo, 2020).

III. ANALYSIS METHODS

3.1 Gaussian Mixture Model (GMM)

In machine learning, there are two areas which are supervised learning and unsupervised learning.

The difference between the two is the approach used to solve the problem statement and the data used in the approach [4].

There is a term in unsupervised learning called clustering in which we find the groupings of data points with certain common characteristics.

Now clustering means finding the set of points which are close to each other compared to other data points.

In our diagram below, we clearly see two sets of clusters or set of data points that are close to each other :

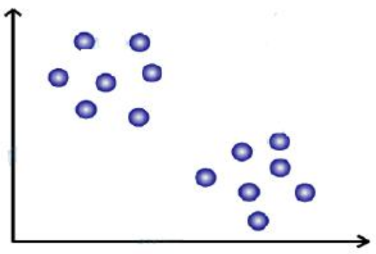

Fig.2: Data points

You can see it in the image below where the two sets are shown in blue and red.

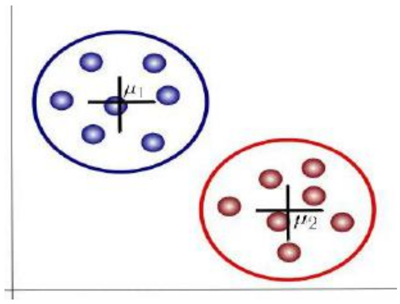

Fig. 3: Groups Gaussian Mixture Model

Gaussian Mixture Model is a function that includes several Gaussians equal to the total number of clusters formed. Each Gaussian in the mixture carries certain parameters which are:

1. An average, which defines the center.
2. A covariance, which defines the width.
3. A probability.

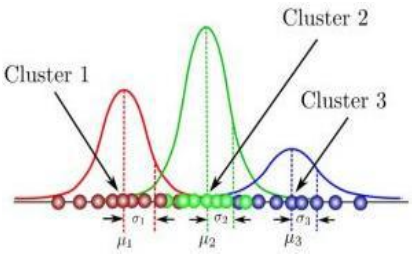

Fig.4: Gaussian Mixture Model 'GMM) clusters

Here you can see that there are three clusters which mean three Gaussian functions. Each Gaussian explains the data present in each of the available clusters.

Since there are three (k = 3) clusters and the probability density is defined as a linear function of the densities of all these k distributions.

$$p(X)= \sum_{k=1}^{K} \pi k \; G(X|\mu k, \Sigma k) \quad (1)$$

Where πk is the mixing coefficient of the k distribution

This enables applications such as object recognition, background suppression and medical image analysis.

Image segmentation: GMM is widely used in image segmentation tasks. By modeling image pixels as a mixture of Gaussian components, GMM can effectively distinguish different regions or objects in an image [5].

The Gaussian mixture model finds applications in various fields, thanks to its versatility and ability to capture complex data patterns.

A Gaussian mixture model is a versatile probabilistic model capable of capturing complex data distributions by representing it as a combination of multiple Gaussian (normal) distributions.

3.2 Deep Learning

Deep Learning is based on a network of artificial neurons imitating the human brain. This structure is arranged in several layers, interconnected with each other.

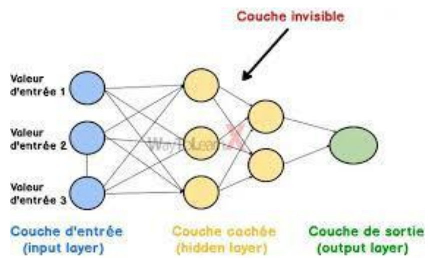

Fig.5: Neural structure

The first layer corresponds to the input neurons and the last one transmits the output results. Between the two are several intermediate layers through which information is processed. This architecture is specific to deep learning and allows each layer to more accurately analyze the input data.

Thus, the deeper the artificial neural network is and therefore contains several layers, the more the system can perform complex tasks. It is able to determine by itself a representation of what it receives, whether it is an image or a text.

With each piece of information integrated, the connections between neurons expand and change. This is why a system with deep learning AI has the ability to learn new things on its own. It also improves its forecasting and decision-making on its own, with no human intervention required. It therefore has the particularity of learning from its own mistakes [6].

Deep learning is therefore comparable to a network with several levels of information distillation operation, where the information passes through successive filters and emerges more and more purified (i.e. say useful for certain tasks).

IV. CALCULATION OF THE VOLUME OF A BIOGAS DIGESTER

The type of digester used in this document, a removable digester, is made of metal and plastic materials and all assembled.

3.3 . How to calculate the volume of a digester? [7]

The size of a micro biogas plant or a digester to carry out methanization (using organic matter such as : animal defection, agricultural waste, etc.)

In general the calculation of the volume of a digester filled with organic waste depends on fundamental assumptions in relation to the daily supply and the water level in the digester.

The digester level can be calculated by the following relationships:

$$VD = Vsg + Vd \quad (2)$$

VD= Total volume of the digester;

Vsg: Gas storage volume;

Vd: Digester volume;

$$Vd = T * Vdm \quad (3)$$

T: Retention time of waste in the digester which is between 30 and 50 days;

Vdm: Quantity of organic waste mixed with the water fed daily into the container;

$$Vdm = W + nL \quad (4)$$

W: Quantity of water used to mix with organic waste;

$$Vsg = h * S \quad (5)$$

h: height of the gas storage from below the ceiling of the digester to the slurry level inside the digester in (m) is generally 0.4m hence:

$$Vsg = 0.4 * S \quad (6)$$

$$VD = (0.4 * S) + nLT \quad (7)$$

The volume of biogas being in KWh, it should be noted that each m3 of biogas can produce 6KWh. [8]

V. RESULTS AND DISCUSSIONS

The objective of this work is to identify the exploitation values of the biomass capable of providing the biogas necessary to power an electric generator. After applying the relationships above we were able to find the range values applicable to digesters, allowing us to have a quantity of biogas necessary to generate electricity. We have a table below, associating the size of the generator, with the capacity of the digester and subsequently identifying the capacity of the types of biomass elements admissible in the digester and the quantity of biogas extracted.

Table.1: Reference table digester size and generator capacity

Digester size(m3)	3.5(m3)	15	2 units of 15 m3	66 m3	2 units of 66 m3
Water level (m)	1.1m	1.25 m	1.25m for each container	1.8m	1.8 m for each container
Capacité(m3)	1.7 m3	8.8 m3	8.8 * 2	12.7	12.7 * 2
Biogas storage capacity (m3)	1	4.9	4.9 * 2	25	25*2
Digester size	1.95 W * 1.65 H *0.98 W	3D *2.5 H	(3D*2.5 H)*2	(6D* 3H)	(6D* 3H) *2
Occupied floor space (m3)	1.87	7.1	7.1*2	29	29*2
Generator capacity to operate kW	1.5KW	5K W	10KW	20K W	50K W

In order to have a good yield of biogas from the digester and have a good Vdm, there are proportions which allow us to have a good yield which we summarize in the table below.

Table.2: Constitution of waste in the digester per Kg/day

MATTER In Kg/day	Digester 3.5 m^3	Digester 3.5 m^3	Digester 3.5 m^3
Rest of human food	25	125.0	475
Pig defection	45	225	855
Cow defection	60	300	1140
Hen defection	26	130	494
Human defection	32	160	608
Rest of fruit and vegetables	65	325	1235

The two tables show us sufficiently how much waste we can have in well-sized containers that can power biogas generators and provide reliable and permanent electricity thanks to our own waste. There is also an indicator table to achieve optimal performance in terms of biogas recovery according to the nature of the organic waste in our possession.

3.4 Gaussian Mixture Model (GMM)

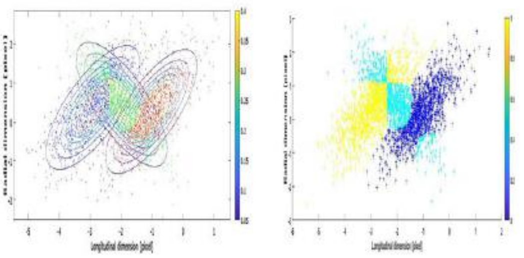

Fig.6: Classification and superposition of flames.

4.2. Deep Laerning

At this level, we have resized all the images to the same size to train the model and validate it.

There is a distribution key for training and validation data:

We have 70% of the data to train, 15% of the data to test, and 15% of the data to test.

The figure below (7) presents the trained data and those validated according to the data distribution key described above.

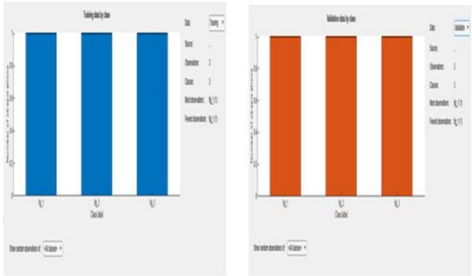

Fig.7: Test and validation data

Figure 8 below presents the complete architectural network of the model to be trained.

This network is subdivided into two layers the Hidden layer and the Output layer.

The first layer, the Hidden Layer, presents the number of neurons to train, which is 14.

The Hidden Layer is a hidden layer between the input and the output of the algorithm where the function applies weights to the inputs and directs them to the output through an activation function. This layer performs nonlinear transformations of the inputs introduced into the network.

The Output layer is the output layer, or final layer of the neural network, where the desired predictions are obtained.

The Output Layer, presents the number of predictions desired on the recorded data and which is 324 predictions.

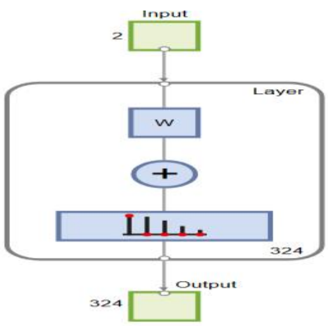

Fig.8: Architectural network of data to train

Analytical prediction relies heavily on machine learning using historical data, statistical algorithms and machine learning approaches.

Predictive analytics is able to determine the probability of events futures in order to extract information from large databases and predict future events.

The figure below shows the results of a combustion model in relation to the data obtained from the combustion chamber (Figure 3.1.). We note that the degree of precision on the prediction is not conclusive in comparison with the data obtained during the classification phase (see Figure 6).

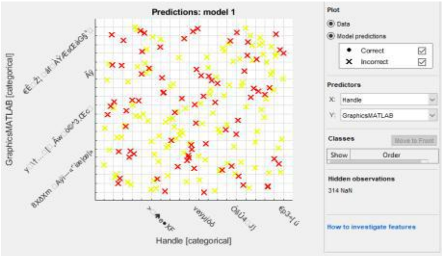

Fig.9: Prediction on model data

The extraction of classification metrics to evaluate the performance of Machine Learning and Deep Learning models is based on the essential foundation which is the Confusion Matrix. Mastering it is therefore an essential prerequisite for fully understanding the performance of a classification model. This matrix is essential to define the different classification metrics such as: Accuracy, ROC (Receiver Operating Curve), F1-Score or even AUC PR.

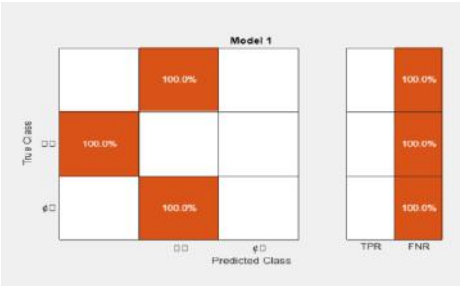

Fig.10: Confusion matrix

The ROC or ROC (Receiver Operating Characteristic) curve is a graph that illustrates the diagnostic capacity of a binary classification system based on the variation in its threshold for discriminating two classes. It can also be called the curve illustrating the performance characteristics of the receiver .

The ROC curve is the plot of the true positive rate (TPR) against the false positive rate (FPR), at different thresholds. This curve indicates the sensitivity as a function of the specificity of the metric.

The figures below (Figure 11) represent the rate of true positives and false positives for our starting data (Figures 6).

By comparing the results from the three separate data sets , we see that the nature of biomass influences the degree of precision in the prediction. Thus, as we can see in the figures below relating to the initial data, that the blue curve relating to cow dung. Gives more precision of true positives while the other two, more precision of false positives.

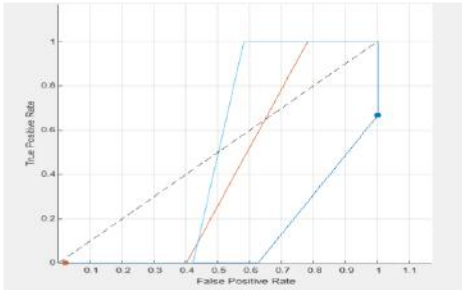

Fig.11: Receiver Operating Curve (ROC)

The analysis of the concentration of the detonation is carried out in this work to validate or confirm the different predictions made above. Thus we can see in the figures below that the concentration is strongly defined in figures 13 and 14 this is to confirm that the more strongly the biomass is loaded, the greater the precision of the reading.

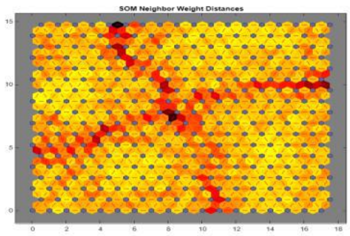

Fig.12:Concentration density

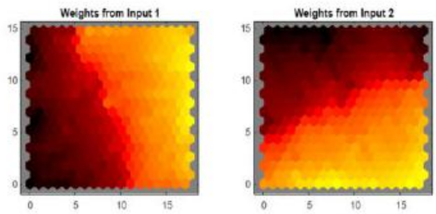

Fig.13: Concentration density

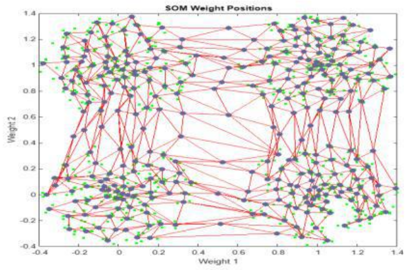

Fig.14: Concentration density

VI. CONCLUSION

The first goal of this work is to show how we can go from biomass via methanization to obtain biogas and subsequently quantify the energy value (electric) in terms of KW but also to carry out an analysis of performance criteria of the energy potential of three types of biomass namely, the rest of human food, pig defection, cow defection.

Something that has been successfully brought out in this article. This demonstrates that a digester mounted on the surface with a well-sized volume, respecting the waste conditioning timing, could give a constant quantity in time t and capable of producing permanent electricity. Table 1 gives an illustrative drawing of the results starting from 1.5 to 50 KW of electricity capacity to be produced with an associated size digester ranging from 3.5 m3 to 66 m3.

The analysis also led us to a conclusion which is that a judicious choice of the biomass leads to good results, such as the observation above that the defection of cows has a great energy potential compared to the other types of biomass under examination.

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