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Energy production and value of biogas from controlled discharge Al-Hoceima Landfill site

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- ✓ Anaerobic digestion

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Abstract

Energy has always been a vital issue for mankind, being aware of the importance of emerging issues, particularly those concerning the environment (Global warming, depletion of fossil resources, pollution, ...) should bring us closer not only to a more rational use of energy, but also to a development and optimization of energy processes going towards the production of renewable energy, green energy that adapt to the concept of sustainable development. Energy from biomass in the form of biogas is one of the most known types of renewable energy. This project falls within this framework, it is conducting a study on the theme "Energy production and recovery of biogas from landfills." The main objectives of this project are:

- ✓ Estimation of biogas production by years (model SWANA).
- ✓ Study of energy recovery variants: the variant selected is (the cogeneration: combined production of electricity and heat).

Nomenclature

G (m^3/an):	Total biogas production at time
W (t) :	Stored waste quantity
L_0 (m^3/t of waste)	Total biogas potential
t (an) :	Time elapsed since start of storage
ti (an)	Latency time (between the start of storage and the production of biogas)
k (an^{-1})	First-order decay time constant
s (an^{-1})	First-order growth time constant
Q	Flow of biogas.
C	Calorific power value of biogas.
E	Electrical efficiency (40%).

1. Introduction

Morocco has clearly announced its will to develop recycling while respecting the social and environmental dimension. It has defined a strategic objective to upgrade 20% of the waste generated by 2020 [2]. This is in level with good international practice. The Government has also opted for the use of the par fiscal tool for the eco-tax to finance the development of valuating/recycling pathways, starting with waste plastic packaging for household and similar waste. The eco-tax was introduced in the 2013 finance law and began to feed the National Environment Fund (NEF) in 2014 for a possible redeployment to support the plastics industry [3].

Biogas consists mainly of CH_4 and CO_2, with low levels of H_2S and other gases. Each of these components has its own problems, as well as displacing oxygen.

CH_4- lighter than air (will collect in roof spaces etc.), explosive (see above).

CO_2- heavier than air (will collect in sumps etc.), slightly elevated levels affect respiration rate, and higher levels displace oxygen as well.

H_2S- (rotten egg gas) destroys olfactory (smelling) tissues and lungs, becomes odorless as the level increases to dangerous and fatal.

In this context, the biogas production and recovery project in a controlled discharge aims to estimate the production of biogas and a study of the valuation variants.

2. Materials and methods

2.1. Study Site

The discharge of Al Hoceima site is a 43 ha controlled landfill site with a burying landfill of approximately 6 ha and is located approximately 16 kilometers in the south of Al Hoceima and approximately 3,5 km in the northeast of Izafzafene.

2.2. Characterization of Waste

The sampling of household waste requires rigorous collection protocols for the representative sample. In the context of this study, the documents we used are the standard AFNOR XP X 30-408, relative characterization of a sample of household waste, standard XP X 30-413, relative to the constitutions of a sample of And standard XP X 30-445, relating to the constitution of a sample of household waste in bulk (pit or reception area) is the method most used today, It proceeds according to the following steps [4]:

- ✓ Emptying on ground the contents of the bucket corresponding to the flow to be characterized,
- ✓ Homogenization of the pile with the bucket of shovel or loader,
- ✓ Collection of a first discarded bucket
- ✓ Collection of a bucket dumped over 4 bins of 300-liter (about 50 kg per bin),
- ✓ Sweepstakes of two bins, weighed, placing contents in bags.

The last two operations are repeated between 3 and 5 times to collect a total of about 500 kg per sample: Elimination of the remaining waste with the charger, Bags labeling.

2.3. Production and biogas recovery

2.3.1. Biogas Production process and factor

The purpose of biogas plants is to generate a gas that contains mainly methane. This biogas production is the result of the methanisation which results from the decomposition of organic matter into biogas by microorganisms in anaerobic conditions. Anaerobic fermentation is one of the processes that contribute to the degradation of dead organic matter into gaseous simple elements and Minerals. One of the anaerobic processes is fermentation which results in the formation of "biogas", a combustible gas. Fermentation is the result of complex microbial activity taking place in two steps:

- ✓ The specific organic substrate which consists essentially of proteins, Carbohydrates and lipids is decomposed by hydrolysis. This is a liquefaction Or gasification with transformation of the molecules into bold acids, salts or even gas,
- ✓ The second is the transformation of its acids, salts or gases into methane and other gases.

2.3.2. Biogas composition

The composition of the biogas varies with respect to the digested matter and the treatment time. Usually the concentration of methane is between 50 and 80% .60% being the value of more frequent.

Further more than methane, the other main gas formed is CO2. Gases with weak concentrations are H2S, NH3 in addition to water vapor to its desaturation point. These latter gases must be treated according to the intended use for the biogas in order not to damage the equipment [6].

Table 1: Average composition of biogas, Taken from truong (2004, P, 8)

Biogas	**CH_4**	**CO_2**	**H_2S**	**NH_3**	**H_2O**
Concentration	55-80%	20-45%	0-1,5 %	0-0,05%	saturated

2.4. Production Estimation of biogas

2.4.1. Evaluation of wastes production

Al-Hoceima CET received 227079 tons of wastes, since 2008, 4 traps are distributed as follows:

Table 2: waste quantities buried at the TEC level

	Volume (m^3)	Quantities (ton)	Operation Time
Trap 1	66721	71393.11	2 ans
Trap 2	37648	40283.36	1 ans
Trap 3	84941	90886.65	2 ans
Trap 4	22528	24104.96	1 ans

2.5. *Modeling the quantity of biogas produced*

Models that describe the processes existing in a TEC will always be influenced by uncertainties due to the impossibility of precisely measuring and controlling all processes occurring in a TEC. In this project we put the focus on model: Model SWANA: Developed by the Solid Waste Association of North America (SWANA). It considers the production of gas of a certain mass of waste during the (For our project we adopted this model) [7].

$$G = W \times L_0 \left(k+s\right) \times s \times \left(1- e^{(-s(t-ti))}\right) \times \left(k.e^{(-k(t-ti))}\right)$$

2.6. *Energy recovery of biogas*

Energy from biomass in the form of biogas is one of the most well-known types of renewable energy; biogas produced is a potential source of energy for the generation of heat and electricity production. However, this biogas constitutes gas mixtures of complex composition, hence the need to purify them before any recovery.

✓ ***The calorific power***

Each gas is characterized by a LCP and UCP,

LCP= The lower calorific Power value (LCV) is the quantity of heat released by the complete combustion of a fuel unit, the water vapor being assumed to be non-condensed and the heat not recovered.
UCP= Upper calorific power value (UCV) is the quantity of heat expressed in KWh or MJ, which would be released by the complete combustion of one (1) normal cubic meter of gas.
Upper calorific power value (LCP) gives the maximum theoretical release of heat during combustion, including the heat of condensation of the water steam produced during combustion.
For biogas:

LCP = 9.42KWh/Nm^3.
UCP= 11.03KWh/Nm^3.

In the case of our project we will take the percentage of methane of 60%, hence we find:

LCP = 9.42× 0.60 = 5.65KWh/Nm^3.
UCP = 11.03×0.60 = 6.61KWh/Nm^3.

We opt our production of LCP: 5.65KWh/Nm^3

✓ ***Quantities of electrical energy produced***

The power P that could be recovered from biogas is generated by the following equation:
With:

$$P = C \times Q \times E$$

✓ ***Choice of biogas electrical recovery technology***

The main technologies for recovering biomass gas are gas engines or dual fuel (injection-ignition) engines or turbines and micro-turbines. They cover a wide range of power, from less than 40 kW to more than 1 MW. Organic Rankine Cycles (ORC) and Fuel Cells (FC) fueled from biogas are also under development, although there is little feedback on these technologies.

Table 3: the different techniques and their level of development.

	Biomas gaz types	Power range	Level of development
Spark-ignition gas engines	Biogas	>40 KW	Marketing dissemination
Spark-ignition gas engines	Gasifier gas	>300 KW	In development
Gas injection-ignition engines	Biogas	<300 kw	Marketing dissemination
Gas turbine	Biogas	>1 MW	Marketing dissemination
Micro turbine	Biogas	<200 KW	In development and dissemination
ORC	Every	>1MW	In development
Stirling	Every	<300 KW	Research and development dissemination
FC	Biogas	>250 KW	Research and development (a commercial offer on MCFC)

✓ ***The engines***

The power of the engines lies between 30 kW and 3,6 MW.

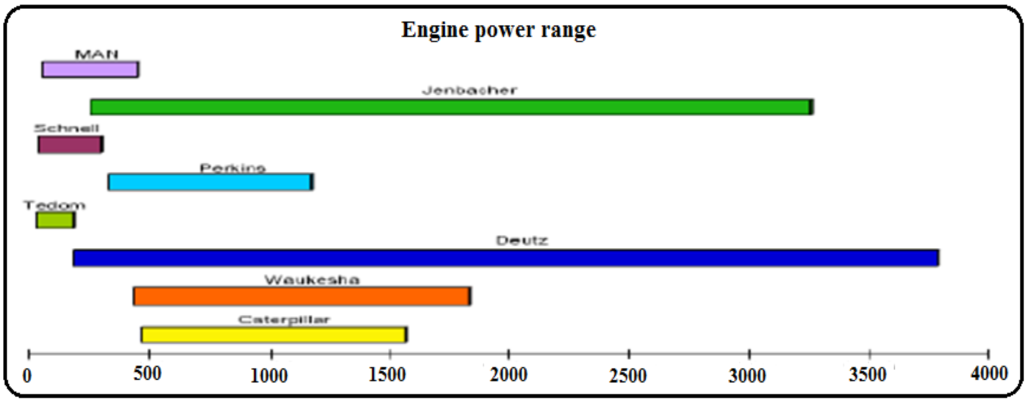

Figure 1: power range of different brands of biogas engines [8].

✓ ***Gas turbines***

The gas turbines are located at very high power from 1,2 to 15 MW.

✓ ***Micro turbines***

Micro turbines are low power machines between 30 and 250 kW.

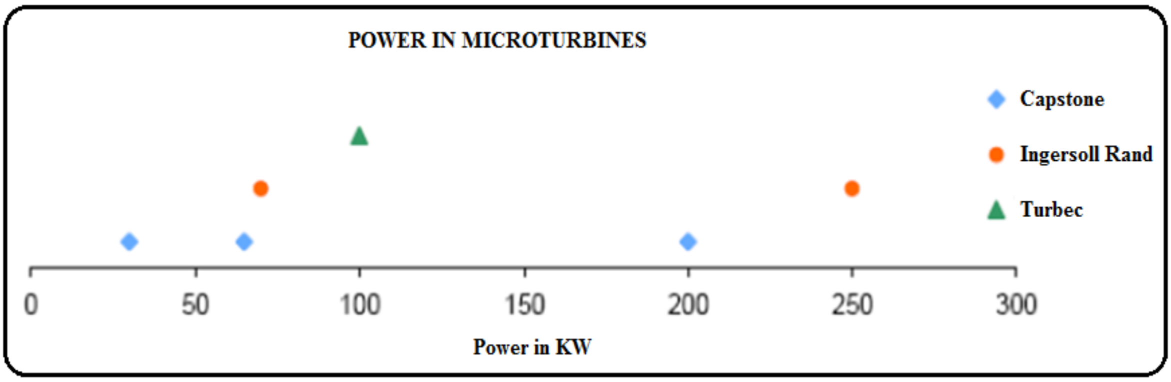

Figure 2: Comparison of the powers of different microturbines [9].

There are still few micro turbines on the market. Currently in France, the micro turbines that are most distributed is Capstone micro turbines.

Criteria for selecting the valorization technology appropriate to the project case:

Gas engine, dual fuel engine, turbine, and micro turbine are the main technologies of biogas valorization developed to date. Each operates in an optimum power range.

Depending on the electrical power that the site can provide, two to three technologies can be envisaged. The valorization technologies according to the electrical power supplied are broken down as well

- ✓ Below 30 kWe: gas engines or dual fuel engine.
- ✓ Between 30 kWe and 250 kWe : gas engine, dual fuel engine or micro turbine
- ✓ Between 250 kWe and 1, 2 Mwe: gas engine or dual fuel engine.

In some configurations, several micro turbines mounted in parallel.

- ✓ Above 1, 2 Mwe: gas engines and gas turbine. Parallel to the power, other parameters determine the choice of the machine. The main factors we considered were: installed electrical power, stability of methane rate, methane content, biogas quality and programmed heat recovery.

2.7. Collection and treatment of biogas

2.7.1. Drainage and collection device

The production of biogas by the mass of waste causes an important increase in the pressure inside the air relative to the atmospheric pressure. Since the permeability of the waste is 10 times greater in the horizontal direction than in the vertical direction (due to compaction), the gas migrates preferentially towards the lateral walls of the trap. The capture and collection system chosen shall:

- ✓ Collect the maximum amount of biogas produced.
- ✓ Maintain a regular supply of biogaz

Once the wells are installed, they can be connected to the collection network of differentmanners. As shown in the figure below:

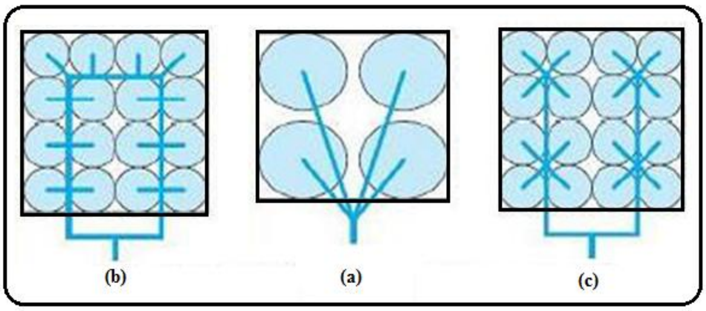

Figure 3: Collection devices of biogas [12]. (a) Each well is connected to an extraction installation by a separate pipe; (b) The wells are connected to a ring line; (c) The wells are connected to each other and then to the extraction unit: used when there are a large number of wells.

Moreover, the pipes must resist the biogas which is very corrosive for the equipment (pipes, pumps ...) and to the mechanical wear due to the compaction engines. It will therefore be necessary to use suitable materials such as the most frequently used HDPE or stainless steel or aluminum alloys [10].

2.7.2. Sizing of terminal pipes

We will size the terminal pipes, those that vontachemin the entire biogas produced at a time t. They can be buried, on the ground or on supports. Linear load losses for HDPE pipes are estimated in the following way:

$$\Delta P / L = 23000 \times d \times Q^{1,82} \times D^{-4,92}$$

For pressure drops of 0.5 mbar / m, we therefore have D = 24 mm. Since this Dimensioning is based on the modeling of biogas production, it is preferable to choose a top pipe diameter as a precaution to 80 mm, so we choose 110 mm PN 10. For whole drains we opted for a diameter of 160 mm PN 10.

3. Results and discussion

3.1. Characteristics of waste

The brute composition of waste is given in the following table:

Table 4: Waste Characterization Results

Type of matters	Percentage %
Organic matter of animal and vegetable origin	65,8
Paper and cardboard	8,9
Plastic products	10,5
Ceramic glasses and debris	1,1
Metals	1,08
Textiles and rags	11,15
Various	1,4

3.2. Biogaz production estimation

The table below shows estimates of biogas and methane production based on the SWANA model.

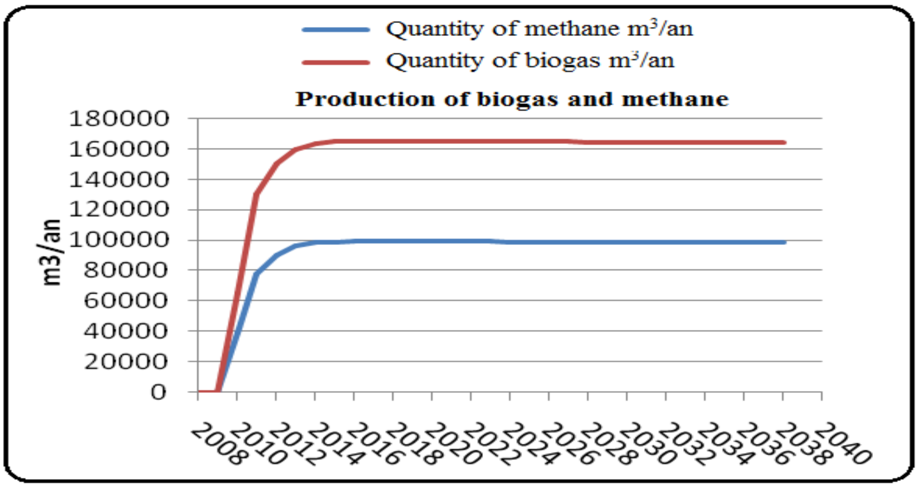

Figure 4: Results of estimating biogas production by years

3.3. Quantities of energy produced

The calculation results are presented below:

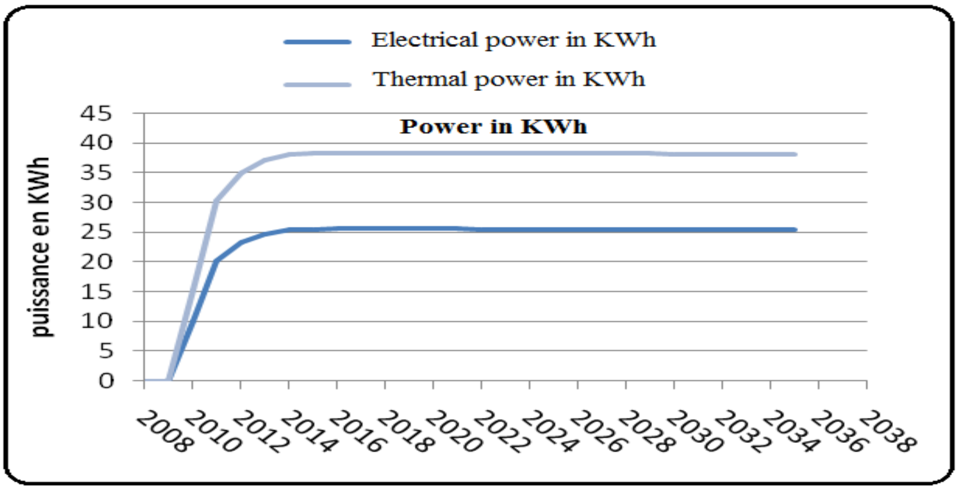

Figure 5: results of electrical and thermal power estimates

3.4. Choice of recovery technology

After having seen the different types of biogas recovery technology and based on the design data, one chooses a biogas thermal engine type TEDOM 28 KW.

Table 5: Characteristic of gas engine TEDOM (Econerphile expert in energy recovery)

	Electrical Power	Thermal Power	Thermal efficiency	Thermal efficiency	Overall efficiency
Eco Bio 30	28 kW	58 kW	29,80%	62,00%	91,80%

3.5. Performance on site Consumption

- ✓ Annual consumption 54000 KW.
- ✓ Annual production: P= 224306, 81 KWh /year, which represents an efficiency of 100% of general consumption of landfill Technical center.

3.6. Valorisation of Thermal Energy

For this, we have chosen to accelerate the evaporation of leachates in the evaporation lagoons, as well as to add a heating system by recirculation of heat through coils (either free or integrated in slabs Heaters in concrete).

- ✓ ***Biogas collection and treatment***

The results of the calculations are presented in the table below:

Table 6: Summary of calculation results

	TRAP 1	TRAP 2	TRAP 3	TRAP 4
Diameter of perforated pipes made of HDPE	160	160	160	160
Wells Diameter at mm	800	800	800	800
Main collector diameter	110	110	110	110
Number of wells	2	2	4	2
Total length of perforated pipes in EHDP 160 mm	20	20	40	20
Total length of pipes in EHDP 110 mm	490			

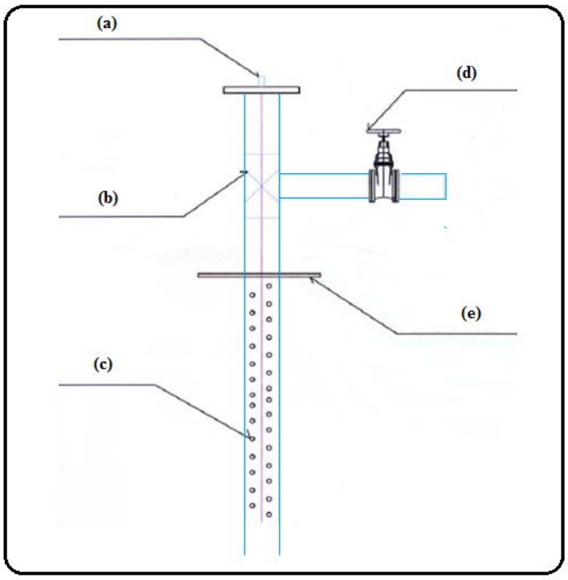

Figure 6: wellhead model

Figure 7: Design results for the biogas collection network

Conclusion

Biogas is produced by the fermentation, in the absence of oxygen, of the biodegradable materials stored in the TEC. It is a natural and spontaneous phenomenon, due to the methanogenic bacteria present in the environment. The discharge biogas is a mixture of CH4, CO2, and trace H2S, O2, residual nitrogen. The formation of this gas is governed by short aerobic and long decomposition processes in anaerobiosis. However, the biological degradation of the waste is influenced by several parameters such as temperature, pH, and the presence of oxygen. The organic decomposition of the waste generates the production of biogas and, in order to quantify this production, a modeling by the SWANA model was carried out for this purpose. The results obtained show that the recoverable power in terms of one year amounts to 224306.81 KW. While the internal need of the site is about 54000Kw / year. This represents a 100% overall consumption of the TEC. Following the content of this study, the following recommendations were made:

- ✓ Think seriously about the success of this project given its social and environmental economic interests.
- ✓ Encourage the installation of methanation projects in the region.
- ✓ Controlled and anticipated communication upstream of the project.
- ✓ Involve the public and private actors involved in the project and be able to bring the participants into a constructive discussion space while managing their differences and avoiding the pitfalls of participation, as this step is key for the development and the implementation of the project.

References

[1] Le Ministère Délégué chargé de l'Environnement, Programme National des Déchets Ménagers et Assimilés (PNDM), 2008.

[2] CEPG, E. JADOUL, Production combinée de chaleur et d'électricité (cogénération): une technologie d'avenir pour réduire la facture énergétique, décembre 2008

[3] Ministère Délégué Auprès Du Ministre De L'énergie, De L'eau et De L'environnement Charge De L'Environnement, valorisation et gestion durable des déchets au Maroc.

[4] ADEME par le groupement INSAVALOR SA – plateforme PROVADEMSE et TERRA SA Coordination technique: Ra faëlle DESPLATS – Service Planification et Observation des Déchets – Direction Consommation Durable et Déchets – ADEME (Angers) VERSION FINALE 2014,

[5] S. BOYER, D. LABRUNIE, E.SEGARD, fabrication de biogaz: synthèse de pétrolepar fermentation à partir de déchets organiques - projet scientifique en laboratoire. Janvier2009.

[6] J. Alberto et al, Bio méthanisation Des Déchets Putrescibles Municipaux – Technologies Disponibles Et Enjeux Pour Le Québec, juillet 2010.

[7] Youcef KEHILA et Guy Matejka Conception Exploitation Des Centres De Stockage Des Déchets En Algérie Et Limitation Des Impacts Environnementaux, 2011.

[8] ADEME. « Gérer le gaz de décharge. Techniques et recommandations ». Guides et cahiers techniques de l'ADEME. 2001.

[9] RECORD, Techniques de production d'électricité à partir de biogaz et de gaz de synthèse, 2009, 253 p, n°07-0226/1A.

[10] ADEME. « Gérer le gaz de décharge. Techniques et recommandations ». Guides et cahiers techniques de l'ADEME. 2001.

[11] RECORD, Production et distribution de biogaz. Santé et sécurité des opérateurs, 2013, 223 pages, n°11-0673/1A

[12] BILLARD Hervé. « Centres de stockage des déchets. Exploitation ». Techniques de l'ingénieur.

[13] Nicolas Dupont. Valorisation du biogaz de fermentation : combustion catalytique. Autre. Université Claude Bernard - Lyon I, 2010. Français

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