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A CURRENT VISION

Methodology for the selection of an electric biogas generator for the use of Organic Solid Waste from vegetable sources

Metodología para la selección de un generador eléctrico de biogás para el aprovechamiento de Residuos Sólidos Orgánicos de fuente vegetal

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Abstract

Through this document, it is intended to provide a guide for the acquisition of a 10kW electric power generator with biogas, using a series of steps that are proposed in this article for the adequate obtaining of the generator that comply the specific demand of this case and will be installed in the Market Square of Fusagasugá (Colombia), the main collection center of the municipality and that constitutes this case of study. The methodology consists in the compilation of the options for their acquisition according to market availability, electrical and mechanics specifications, accessories, nationalization and internal transport procedures.

Keywords: biogas, electrical generator, organic solid waste from plant sources.

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Resumen

Por medio de este documento, se pretende brindar una guía para la adquisición de un generador de energía eléctrica de 10kW a partir de biogás, utilizando una serie de pasos que se plantean en este artículo para la adecuada obtención del generador que cumpla la demanda específica de este caso y sea instalado en la Plaza de Mercado de Fusagasugá, principal centro de acopio del municipio y que constituye este caso de estudio. La metodología consiste en la recopilación de las opciones para su adquisición según disponibilidad en el mercado, especificaciones eléctricas y mecánicas, accesorios y los respectivos trámites de importación, nacionalización y transporte interno.

Palabras clave: biogás, generador, residuos sólidos orgánicos de fuente vegetal.

1. Introduction

Electricity generation with biogas is an alternative energy source that allows the use of organic solid waste (OSW), whose final destination is usually municipal landfills. In this context, it is intended to take advantage of the OSW from the municipal market place, for the generation of biogas that will feed a power plant.

This research is framed within the execution of the Prototype Project for the Electric Power Generation System from Organic Solid Waste in the Marketplace of the municipality of Fusagasugá, Colombia, linked to the call for MinCiencias 829-2018 Call for R&D projects for biological-based technological Development-Cundinamarca. The authors of this document are members of the student's young research SEA (Alternative Energy Research Seedbed), attached to the GIEAUD research group.

It begins with a contextualization that allows us to understand the importance of this project in the urban scenario, the background and the actions that have been carried out by the government of Fusagasugá, Colombia. Then, a compilation of the technologies available in this area will be made, observing the characteristics of the internal combustion engines for these generators, among other possible devices. Subsequently, the procedure followed for the acquisition of the machine is described: what variables will be taken into account, the order of operations, and the information necessary for the implementation of an electric generator that meets requirements for the project.

This document will conclude with a synthesis of the methodology followed for the implementation of the generator and its subsequent and possible installation.

2. Development of the topic

2.1. Theoretical framework

The Energy and Gas Regulation Commission of Colombia, in the document CREG-056 of May 22, 2009, establish the next: “Biogas is a combustible gas that is generated in natural environments or in specific devices by the biodegradation reactions of organic matter, through the action of microorganisms (methanogenic bacteria, etc.), and other factors, in the absence of air (anaerobic environment). (…) This biogas is a mixture made up of methane (CH4) in a proportion ranging from 50% to 70% and carbon dioxide (CO2), containing small proportions of other gases such as hydrogen (H2), nitrogen (N2), oxygen (O2) and hydrogen sulfide (H2S2)” [1].

The use of electricity generators by biogas allows to give a new use to the waste, taking advantage of its energy potential “the calculations indicate that of the 11.3 million tons of waste produced per year in Colombia, at least 9.6 million they could be used ” [2].This project focuses on the use of organic solid waste from vegetable sources through electrical generators, especially internal combustion, seeking to promote the implementation of this technology in Colombia and thus reduce its environmental impact as a measure of obtaining services. Electricity generation from biogas is a process of implementation of non-conventional energy sources, being relevant because “the generation of biogas and obtaining electrical energy to supply […] turns out to be highly attractive in terms of the savings that can obtain" [3].

Today, various sites seek to promote resource use plans, and the generation of energy from organic waste is one of the saving methods. An example of this is in Michoacán, Mexico where livestock excreta residues are used to feed generators, "Representing an electrical energy saving of 4.23% that corresponds to an amount of approximately $ 18,300,000 pesos for 2013"[3]. Generators, used correctly, can achieve savings for a satisfactory amount of time with respect to the investment, counting on the resource for their activation "Considering 50% by volume of CH_4 and a useful life of the project of 21 years" [3].

The Update of the Solid Waste Management Plan (PGIRS) of Fusagasugá 2016 - 2027 is currently in validity [4], whose objective is to guarantee the continuous improvement of waste management and the provision of the cleaning service in the municipality of Fusagasugá in Colombia, allowing, among other things, the use of waste: “for a decade the Government of Cundinamarca has been warning on the serious problem that the department is experiencing with its waste: its landfills only have a useful life of 30 years " [5]. The document mentions the initiatives that are in place for the use of waste, both from the Mondoñedo landfill and those generated within the marketplace: transformation of organic material to composting, reuse, recycling and energy recovery.

There are various technologies on the market for this energy recovery and / or transformation process. In the *Landfill gas energy technologies handbook* [6] from the Oil and gas institute, National Research Institute - Poland, there is a compilation of the machinery commonly used in the use of landfill biogas (LFG), which has a higher quality than OSW biogas due to its composition. This document contains a detailed description of the operation of reciprocating or internal combustion engines and each of their stages, as well as a compendium of generators available in the industry; it also contains an overview of Bryton cycle turbines, micro turbines and Stirling engines.

Bove and Lunghi in the document *Electric power generation from landfill gas using traditional and innovative technologies* [7] set out the conditions of use of solid waste in Italy, differentiating between composting, incineration and landfill, the latter being the most used (around 70%). The article includes a table of the most common composition of waste dumped in landfills using data from three of them, one in the United States, with methane between 45% and 60% of the total composition; Other components such as carbon dioxide and oxygen are also mentioned. It also includes advantages and disadvantages of the most used technologies and mentions some other technologies for the use of biogas, such as turbine systems based on the Organic Rankine Cycle, fluid carbonate fuel cells and solid oxide fuel cells.

In the document *Generating electricity from biogas captured from urban solid waste: a practical theoretical analysis* of the Inter-American Development Bank [8], a description of the technologies available for the generation of electricity from landfill biogas (GRS) is made, considering advantages and disadvantages of each one, and the sources of greenhouse gas (GHG) reduction are analyzed, focusing on the potential of some Argentine cities. Here they summarize some treatments and uses of biogas, electricity production technologies with biogas, and share a brief environmental study of current effects and the improvement of environmental conditions with this kind of initiative.

As a regional reference, we can cite the Biogas Doña Juana project (Bogotá - Colombia): Energy production cycle from landfill biogas. This includes data such as the expectation to reduce around 820,000 tons per year of greenhouse gases, the composition of the landfill gas, and a description of the biogas electricity production cycle. They have 3 plants, the first start-up in 2016; Currently, they reach almost 23MW of electricity generation using internal combustion engines with the use of reciprocating cylinders, similar to the generation plant proposed here.

This mode of energy production can be achieved through the implementation of equipment for generation such as: internal combustion engines (figure 2), gas turbines (figure 1), organic Rankine cycle gas turbine systems (figure 3), among others.

Figure 1. Gas turbine generator [16]

Figure 2. Caterpillar Internal Combustion Engine Generator [17]

Figure 3. Organic Rankine Cycle Power Plant [18]

The organic Rankine cycle is based on the traditional cycle using water instead of propane; the disadvantage is its low efficiency due to its fuel change. The Stirling cycle engine is rarely used due to its external combustion, its high impurity and being large, its use is very low in projects of this type; something similar happens with solid oxide fuel cells "which are of great help for the environment and generate carbon monoxide that can be used as fuel" [7] but its efficiency for power generation is very low.

As can be seen in Table 1, reciprocating internal combustion engines are the most used to carry out the gas-to-electric energy conversion process due to the ease and considerable efficiency shown by the process, they also “represent the most used technology for the electrical energy […] this reason is mainly due to the compatibility of power with economic viability " [7]. In addition, they have a robustness that allows the increase of the durability of the machine and an increase in the useful life if it is handled without any excess effort, reaching an efficiency of up to 33% [7].

Table 1. Energy efficiency of generating machines [5]

Machines	Electrical efficiency	Fuel consumption (kJ / kWh)	Emissions (µg / kJ)	
			NOx	CO
Fuel cells	50%	7174	NA	1.4
Stirling cycle	38%	9390	3.11	15
IC engine	33%	10972	56.6	56.6
Gas turbine	28%	12872	15	19
Rankine cycle	18%	19202	16	18.9

Internal combustion engines for power generators are the most used and studied in the industry, not only for electricity but also for obtaining energy that generates movement with good performance in the face of load fluctuations and fast maintenance [8], increasing its reliability. This guide was developed based on the application of the same for the acquisition of a generator with an internal combustion engine.

2.2. Development

2.2.1. Problematic

This document is a guide for the implementation (search, characterization, purchase and import) of an electric generator from functional biogas to obtain power, this as a strategy for promoting the use of non-conventional energies and specifically the use of OSW at various sites.

Said machine could, depending on the need, be an internal combustion engine, a turbine, among other generators. In addition, the use of filters (desulphurization and dehydration tanks) is recommended for the treatment and improvement of the biogas quality.

Taking into account the above, the specific characteristics of the machine that is intended to be used for the generation must be determined, in addition to meeting the demand, it must comply with the proper installation in its common work site, therefore, it is necessary to know the accessories that could become necessary, such as isolation, connections to the local network and additional requests or procedures within the purchase and import process.

2.2.1.1. Study of the supply in the market

This document offers quotes made in Colombia, Argentina and China. The search at the Colombian level offers information from few suppliers, which are mainly related to fully treated gas generators, that is, they work only with line gas or 100% methane. As a reference there is the NOVATION company, which includes among its recommendations to acquire, in addition to the power plant, biogas treatment equipment (an H2S filter - hydrogen sulfide filter that will be discussed later), a dryer and a blower to give pressure to the biogas and send it to the generator.

The results obtained during the search in Argentina expose high costs that, we believe, could not be covered by small agribusiness entrepreneurs who would also be potential clients of this sector. Among the available suppliers consulted is *Mercados Renovables SLR*, an Argentine company that imports generators from the company AQUALIMPIA, designed in Germany and assembled in China. The same equipment includes the filter, either air or oil, among other accessories for the control and supervision of operations. There is also the concessionaire in Colombia GECOLSA CATERPILLAR with a supply of biogas generators between 76 and 3370 kW; additional specifications include soundproof booth, automatic transfer to network, installation and commissioning, working height of the equipment above sea level, among others; Costs go up to USD20,000 for the lowest power generator set.

Figure 4. CAT Biogas Generator Catalog [19]

BIOGAS

MODELO	POTENCIA ELÉCTRICA (Kw)	RPM
G3306	76	1,800
G3406	137	1,800
G3412	194	1,800
CG132-8	400	1,800
CG132-12	600	1,800
CG132-16	800	1,800
G3516A	824	1,200
G3516A+	1,015	1,200
CG170-12	1,200	1,500
CG170-16	1,550	1,500
G3520C	1,622	1,200
G3520C	1,936	1,500
CG170-20	2,000	1,500
CG260-16	3,370	900

Finally, the search was carried out in China, opting for the use of online applications for the acquisition of heavy or industrial machinery. The most effective one to carry out this consultation was Alibaba, the online trading platform of the private Chinese consortium Alibaba Group. Here you can find a multitude of Chinese companies with a supply of generators of any type and with a wide range of powers. Once the quotes have been requested, each supplier offers its catalog of both generators and accessories available for the correct operation of the generating sets.

In general, the lowest costs were obtained from the Chinese companies on Alibaba, in addition to offering various accessories to complement the power plant. Quotes are usually given in dollars, so it is important to take into account fluctuations in the value of this currency.

2.2.1.2. Information for the selection

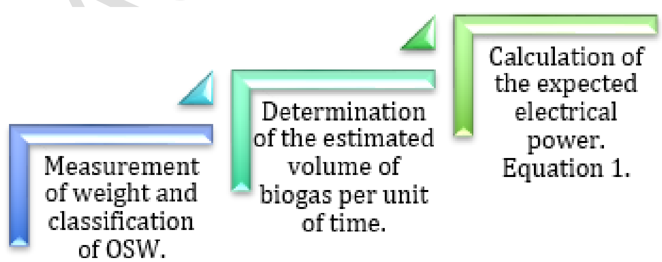
Different considerations must be taken into account so that the generator meets the requirements demanded by the project. The following comparison criteria are proposed for a second preliminary equipment analysis:

- The costs of the machines (generator and accessories), taking into account variations in their price due to external causes (mainly fluctuations in the dollar).
- Generated power: motor specifications such as its nominal power, nominal current, thermal efficiency and so on, sufficient to satisfy the demand.
- Transportation: Shipping cost (insurance and freight, named destination), import parameters required at the time of assembly.
- Mounting conditions: noise level, type of insulation required, combination with the local electrical network, dimensions and weight of the equipment, and clarity regarding its use and specifications.

Having these filters clear allows to guarantee that the generator meets the needs of the project to be executed, and also that it does not generate cost overruns such as damage to the structure, failures or errors in the combination with the electrical system or an envelope. generator effort.

2.2.1.3. Calculation of electricity generation capacity

Figure 5. General procedure for calculating generated power



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As a general model, the first piece of information obtained from an OSW initiative is the weight of waste generated per day. According to Colombian regulations, after knowing the weight, a classification scheme for non-hazardous solid waste must be met, which is divided into three large groups: usable, non-usable and biodegradable organic [10]; the latter includes food waste, cutting and pruning of plant materials and litter, the main components of the biomass that produces the biogas used here. These wastes should not be stored for more than 48 hours due to their degradation properties [11].

Before selecting the power plant, a physical-chemical characterization of the waste must be carried out to know its composition, the main components being methane, carbon dioxide, nitrogen, and sulfuric acid [12]. During a second phase, the aim is to determine the optimal parameters to obtain a high potential in the biogas with methane concentrations higher than 50% for a correct operation of the machine.

To calculate the energy potential of the biogas and with it the electrical power of the generator to be used, the volume of the same, the continuous working time and the value of the LHV must be known; then, the calories are transformed into kilojoules, this is divided by the work time in seconds and kW are obtained. The LHV is a measure of the amount of energy per unit volume that can be released when the biogas combustion occurs, and has a value of 5000kCal / m^3 for landfill gas according to the Andalusian Energy Agency.

$$\frac{V * LHV}{t} = P_W \qquad (1)$$

Where:

V = volume of biogas available

LHV = Low Heating value

t = time

The range of efficiencies of the most common machines for these applications fluctuates between 18% and 33%, so it proceeds to calculate lower and higher power multiplying the potential of the biogas by its value for the final selection based on average data.

2.2.1.4. Selection of filters for biogas

Biogas contains impurities and polluting gases that damage equipment if it is not filtered beforehand. It contains different pollutants such as hydrogen sulfide (H2S), halides and other silica compounds, as well as moisture, siloxanes and suspended particles that have to be reduced to guarantee a long useful life of the equipment. During the combustion process, hydrogen sulfide and halogenated compounds can form corrosive acids such as H2SO4 (sulfuric acid), HCl (hydrochloric acid), and HF (hydrofluoric acid) that react with engine parts. Biogas always contains hydrogen sulfide, so it is regular to purchase a filter for this compound to avoid corrosion damage in the internal combustion engine [13].

Figure 6. Filtering systems.

Source: quotes online.

For low power generators (less than 100kW), filtering systems consisting of desulfurization tanks and dehydration tanks are recommended, preferably in stainless steel, since the effects generated by H2S and humidity are highlighted. It is also necessary to consider the filter medium: for the hydrogen sulfide, the filter beds of Fe2O3 (iron oxide) work, also known as iron sponge, whose intention is to cause the formation of iron sulfides by removing the H2S [14]; the most common filter medium to remove moisture is a cobblestone bed.

2.2.1.5. Additional accessories

In addition to the filters, each supplier will offer a list of possible accessories that adequately complement the power plant, these can be, for example, heat recovery, water pumps, dryers, blowers to give pressure to the gas, parallel grid system for combination with the local electrical network, among others.

Another important feature to take into account is the need for isolation for the generator, since costs can be reduced by choosing an open type system or raising them when an anti-noise canopy is required. For the open type, it was confirmed through quotes and suppliers that noise levels will be less than 71dB, which is within the range allowed by Colombian legislation (maximum 75dB).

2.2.1.6. Additional import costs

These costs refer to the value added to the purchase when the equipment has to be imported from another country. Depending on the characteristics of the element and its place of origin, the proper customs procedures must be carried out to allow the nationalization of the generator and its proper transport to the installation area.

According to Dian “Once the merchandise is found in Colombia in the Customs Warehouse, it is recommended to request authorization to carry out a pre-inspection prior to the presentation of the Import Declaration and other documents if the import value is equal or higher to USD5,000, the ANDEAN DECLARATION OF THE VALUE IN CUSTOMS must be filled out and The liquidation of Customs taxes (Tariff Tax and VAT) is done through the IMPORT DECLARATION”.

According to the Customs Statute (Decree 2685/99) they will be able to act directly before the DIAN “Natural persons who make imports that individually do not exceed the value of one thousand US dollars (USD1,000), who must act personally and directly, and the travelers in their luggage offices".

In the case of imports greater than one thousand US dollars (USD1,000), the services of a customs agency must be hired to carry out this process.

To do this, certain information is required for the database of the customs company, as attached in the following list of requirements:

- Check list update
- Customer knowledge sheet
- General mandate format to the customs company
- Minutes of visits to importers / exporters

The files of the specifications given by the supplier for the selected generator are included in the necessary data to make the proper quotation, the costs of each of them will be obtained taking into account their shipment to the most favorable port of discharge and thus obtain a value approximate of this processing. Keep in mind that this process generally does not include the costs of:

- VAT
- Free to upload / download
- Any other service not specified
- Expenses to Third Parties such as: releases, VUCE, Good Views, Storage, Uploads and / or downloads, etc.

In addition, it is necessary to have the proper documentation from the generator company that will carry out the sale of the equipment.

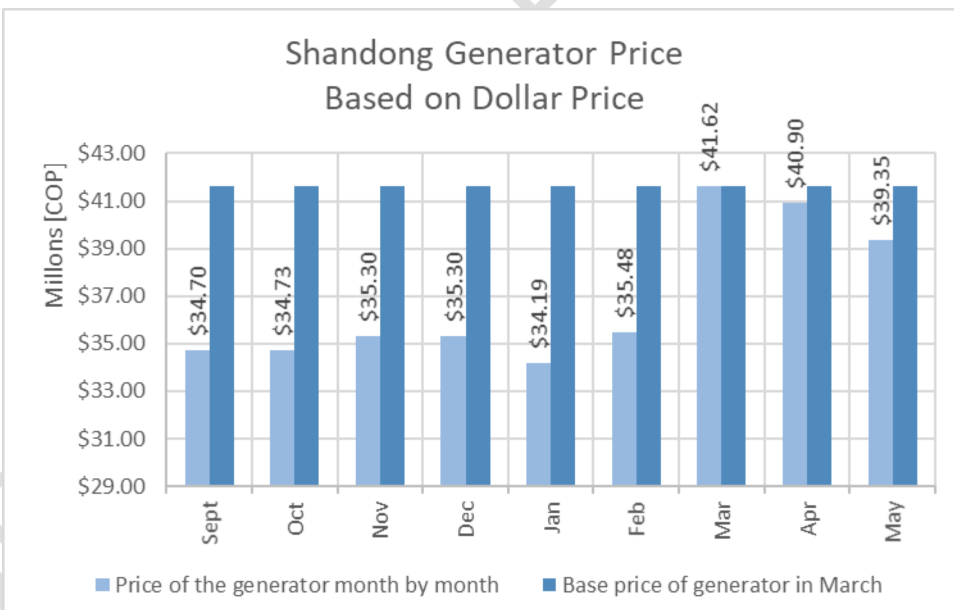
- Register of manufacturers and importers of the SIC, you can do it directly on the website www.sic.gov.co.
- Certificate of conformity with technical regulations. It must be issued by your provider.

- Supplier Declaration of Conformity, issued by the supplier.

3. Conclusions and recommendations

The way in which this methodology will be applied for the implementation of a biogas generator will depend on the needs of each project. You have to take into account the multiplicity of options that the market has, the different suppliers, the accessories they offer and you must be very careful at the time of purchase, since the price of the base currency will always have a considerable impact. For example, the following table shows the variations in the price of a generator month by month, taking the dollar as the reference currency and the price given by the supplier in the month of March 2020 as the reference value, the conversion to Colombian pesos.

Figure 7. Variation of the generator price in COP depending on the variation of the dollar.



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It is recommended to carry out the physical-chemical characterization of the biogas before purchasing the generator, as it works as a guide to correctly determine the expected power and the quality of the biogas to be used; Suppliers do not recommend biogas with a methane content lower than 50% as it interferes with the efficiency and proper functioning of the mechanical parts of the generator, and also increases the probability of corrosively.

It is important to consult the maximum noise levels allowed according to the area where the generator is to be installed, since, as mentioned, not implementing the anti-noise canopy can reduce the price of the generator by up to 20%. It must also be taken into account whether or not it is necessary to link electricity generation with the local grid for the sale of surpluses, since the parallel grid system represents a significant cost when compared to the base price of a low-power generator.

Determining the accessories is imperative. It is not recommended to avoid the use of biogas filtration and purification systems, but it is possible to consider optional accessories such as heat recovery units, blowers or dryers. It is advisable to compare the costs associated with the chosen port of discharge, since the port of Buenaventura can be seen as a reference option without taking into account the costs associated with internal transport within the country.

Finally, the entire procedure for obtaining an electric power generator by biogas was detailed. A model was proposed for the determination of the biogas potential and expected electrical power, the consideration of additional specifications and / or accessories, the search and selection of the definitive power plant, and customs advice for importation. It is expected that these references meet and address the needs associated with the implementation of these power plants that represent an option for the energy transition in the country.

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of the SEA seedbed (UD's Alternative Energy Seedbed), attached to the GIEAUD research group (Alternative Energy Research Group of the District University).

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