ENERGY RECOVERY OF BIOGAS GENERATED IN LANDFILLS FOR MANUFACTURING HIGH QUALITY CERAMIC PRODUCTS

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SUMMARY: The project focus on using the biogas, produced in the Can Mata landfill, as an alternative fuel source in a ceramic factory. This is the first application of this technology in Spain, and one of the first experiments of its kind in Europe. The new process design means that 83% of the energy consumed in the ceramic factory comes from a renewable energy source, thereby avoiding 18,005,040 Kg of CO2 emissions/year. Moreover, in the landfill, 80% of the energy available from the collected biogas is been recovered.

1. INTRODUCTION

The CESPA group, which belongs to the FERROVIAL construction and services group, is a leader in the environmental sector in Spain, specializing in waste management and environmental services.

CESPA is committed to sustainable development and, in order to achieve its sustainability targets, it supports innovation, in its broadest sense: innovative approaches to corporate development, and technological innovation aimed at improving processes and reducing the environmental impact of its activities.

CESPA is aware of its activities impact on greenhouse gases, particularly with regard to its landfill management business, which is currently one of the company's most important activities. It is, therefore, taking steps to reduce gas emissions from landfill sites.

One such initiative worth mentioning involves biogas collection and recovery systems, which are currently installed in 37% of the landfill sites managed by the company, where 61% are producing electricity from the biogas collected, and 31% are using biogas in the leachate treatment.

An example of the innovative approaches applied to process improvement, which is also helping to reduce the environmental impact of the company's activities, is the energy recovery of biogas for manufacturing high quality ceramic products.

The geographical location of the Can Mata landfill site at Els Hostalets de Pierola (Barcelona), owned by CESPA S.A., and the ceramic factory owned by Cerámicas Piera S.L., has enabled both companies to conduct a pioneering project in Spain, and one of the first experiments of its kind in Europe: the energy recovery of biogas and the reduction of fossil fuel

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consumption in manufacturing high quality ceramic products.

The aim of the project was to research and design a system for recovering biogas produced at the Can Mata landfill, and converting it into an alternative fuel source to power two kilns in the ceramic factory.

The main objectives:

- Technical objectives. To study the properties of the biogas and its feasibility for use in burners, and to study its homogeneity, guarantee of supply and the effect any variations could have on the quality of the final product (high quality facing brick).
- Energy objectives. To recover a by-product (biogas) from a registered landfill for use as an alternative fuel source, (the gas is currently being burned off using gas flares, which is a waste of its potential energy), and also to provide a new alternative to the Renewable Energies plan proposed by regional, national and European governments.
- Environmental objectives. One of the main causes of the greenhouse effect is volatile organic compound emissions (mostly methane (CH4)), which is the main component of the biogas obtained. These emissions, which damage the ozone layer and therefore contribute to the greenhouse effect, can be minimized by designing and using this gas more efficiently. The same occurs is true with CO2 emissions, and consequently, this project makes a worthy contribution to complying with the Kyoto Protocol.

The recovery of biogas for use as an alternative fuel source, is much more environmentally friendly than using conventional energy sources.

2. PROCESS DESCRIPTION

2.1 Previous situation in the Can Mata landfill

The Can Mata landfill site receives 600,000 tonnes of waste per year, and when this decomposes, it generates approximately 2,500 cubic meters of biogas per hour.

The biogas produced in the landfill comes from the decomposition of the organic waste. The biogas is mainly composed of methane (CH4) and carbon dioxide (CO2), both of which are the main gases causing the greenhouse effect, with methane having a greater global warming potential (21 times higher than CO2).

Moreover, the correct management of the landfill supposes that the biogas must be extracted from the landfill using reception wells installed along the landfill, and transported as far as the facilities where it will be used.

Before the project, only 32% of the biogas collected was used to produce energy via a cogeneration motor and, in the leachate dryer treatment, the rest was burned in a flare.

2.2 Previous situation in Cerámicas Piera

At the ceramics factory, the two continuous brick producing kilns, with a production capacity of 75,000 Tn/year and 45,000 Tn/year respectively, used to use fuel-oil and natural liquid gas as their energy source. They are also currently equipped with cogeneration motors, which thermal energy is used for the kilns.

2.3 Energy recovery of biogas for manufacturing high quality ceramic products

In order to know whether the project could be of interest to both parties, it was necessary to conduct an initial stage, involving a technical and economic viability study.

As for CESPA, the biogas constitutes a fuel source that is not homogeneous throughout the life

of the landfill. As is well known, the biogas originating from a landfill is mainly composed of methane (50-60%) and carbon dioxide (40-50%). In the project's technical viability study, a series of characteristics of biogas production in the landfill were proved, which meant it had to be conditioned to be used in the kiln burners in the ceramic factory:

- variable production – owing to its varied composition, it is difficult to use in continuous processes that require a constant and stable fuel supply. This meant that an in-depth study of the landfill's current and projected condition was required, and a gas production curve had to be plotted to provide minimum guarantees for its feasibility for use in the plant.
- low calorific power - the lower heating capacity (approx. 50% that of natural gas) is a biogas characteristic. To compensate for this, the dual energy design to fuel the kilns was backed up by a sophisticated heat regulation system to avoid possible problems in continuous processing. A low heat producing fuel was adapted to meet the requirements of a continuous process, without affecting the final product quality, by designing and installing a dual heat supply system that meant the kilns could use a combination of biogas and natural gas that was automatically adjusted to meet heating requirements.
- impurities content (H2S, siloxans,..) - impurities could damage the final product, so these had to be identified, minimized and/or eliminated.
- high humidity
- variable pressure

An exhaustive study of the composition of the biogas properties and the guaranteed methane recovery was also made. On the other hand, studies then commenced to determine the effect that the biogas properties had on manufacturing processes, and on final product properties and appearance.

Periodical sample testing and analysis is recommended to ensure that compound content levels do not exceed current levels. During the first few weeks of operation, the system was regulated and finely tuned.

During this period the following aspects were monitored:

- Determining whether pressure levels would be high enough to supply 2 continuous kilns, and to serve peak demand periods as required by all burners
- Determining whether the system was capable of adapting to abrupt supply level changes caused by the intermittent movement of shuttles.
- Determining whether firing temperatures remained high enough during the entire process, unaffected by the use of a gas with a lower heating capacity.
- Determining whether the automatic changeover from biogas to natural gas worked properly and as rapidly as planned.
- Determining whether final product quality, particularly color, registered significant changes.

As for Cerámicas Piera, the supply requirements were:

- High availability and continuous operation (more than 8000 h/year)
- Impurity-free biogas
- Low humidity
- Constant supply pressure

To satisfy all this requirements, it was necessary to use the facilities and equipment that enable the biogas to be included in the ceramic manufacturing process.

After this initial stage involving a technical and economic viability study, it was clear that the project could be of interest to both parties, and the decision was made to begin a cooperative study and design project for the ceramic factory to use the biogas as an alternative fuel and energy source for the ceramic kilns.

During 2002, CESPA proceeded to design and build the gas extraction plant, along with the pipeline needed to transport it from the landfill to the factory. Cerámicas Piera designed the automatic control system needed for the kiln to automatically regulate its calorific needs (biogas+natural gas) and designed the combustion equipment (burners), respectively.

3. EQUIPMENT AND NECESSARY FACILITIES

As for Cerámicas Piera, the facilities had to be adapted to supply a continuous process with a fuel that has a low calorific power, without this affecting the product. This was done by incorporating a dual heating supply system in the kilns, which combines biogas and natural gas according to heating requirements. The new burners and fuel injectors were adapted to specific biogas properties, such as pressure, lower heating capacity and different air-gas stoichiometrics. The burners had to perform equally efficiently using either fuel type (biogas or natural gas), and had to be adapted to perform dual regulation. A software program automatically adjusted for the different gas pressures and working temperatures was used. The main facilities used in Cerámicas Piera were:

- vertical burners
- horizontal burners
- pilot light system to ignite the biogas

As for CESPA, the main equipment facilities were as follows:

- biogas cooling system
- compression group

The gas transport network, between the landfill and the plant, was designed for a gravity-based collection of the condensates produced by the temperature changes occurring during supply stoppages caused by maintenance or breakdown. These condensates are channeled to a point near the landfill blowers to facilitate collection and pumping. A detailed study was conducted on the route and topography between both facilities. The solution was a highly evenly graded slope to channel the condensates, and to ensure there was no accumulation or obstruction point.

4. RESULTS AND DISCUSSION

The previous study carried out showed the technical and economic viability of the iniciative for both parties as:

- The average values of the composition of the biogas properties and the guaranteed methane recovery, Tables 1 and 2, show that the average values obtained do not exceed the guaranteed values.
- The study of quality of the brick produced showed no significant differences from those using natural gas. The following effects on final product colors were noted:
    - In reddish glazes, the use of biogas produces more intense coloring than the browner, darker tones obtained with natural gas.
    - No significant differences were found in other color lines.
- The study to detect alkaline damage to the kiln refractory caused by elements contained in the biogas gave no indication of anything that could damage the kiln elements in the short term, although there was a higher content of sulphur compounds than with natural gas. However, these levels were lower than those registered with fuel oil, which has been used in the same kilns and has had no effect on normal operations. The studies indicate that if the currently stipulated contract levels are maintained, there should be no problem.

Table 1. Average values obtained

AVERAGE VALUES OBTAINED	
Humidity	0.6 %
Nitrogen (N_2)	11 %
Oxygen (O_2)	1.5 %
Carbon dioxide:	39 %
Methane (CH_4)	45 %
Other:	3 %
Hydrogen Sulphide(H_2S)	*550 mg/Nm^3*
Ammonia (NH_4)	*70 mg/Nm^3*

Table 2. Guaranteed values

GUARANTEED VALUES	
Humidity	$\leq$ 0.75 %
Nitrogen (N_2)	$\leq$ 15 %
Oxygen (O_2)	$\leq$ 3 %
Carbon dioxide:	$\leq$ 45 %
Methane (CH_4)	$\geq$ 43 %
Other:	$\leq$ 4 %
Hydrogen Sulphide (H_2S)	*$\leq$1,500mg/Nm^3*
Ammonia (NH_4)	*$\leq$ 150 mg/Nm^3*

Thanks to this initiative, it was possible to use 1,200 Nm3/h of the generated biogas to supply the continuous ceramic kilns. The combined process started at the end of 2002.

After 4 years of continuous operation, the results are fully satisfactory. Consequently, to date, the fuel change involved in this project has produced highly satisfactory results. No reduction was noted in the final product quality or in the facility's overall production capacity. Production remains at the same level as before the biogas was used.

Moreover, CESPA benefits from the sale of the gas, and CERÁMICAS PIERA obtains a very low cost fuel, which considerably reduces the manufacturing cost of its final product, thus increasing the company's market competitiveness.

In 2003, the energy balance of the combined process for Cerámicas Piera's consumption of 1,200 Nm3/h of biogas, reveals that the biogas is the main energy source in the ceramic factory process, representing 83% of the energy consumed. And in the Can Mata landfill, 80% of the biogas is recovered through this new application, leaving just 20% of the biogas un-recovered.

Table 3. Energetic balance

LANDFILL		FACTORY	CHANGES
PRODUCTION	**PREVIOUS SITUATION**	**PREVIOUS SITUATION**	***PREVIOUS SITUATION***
Biogas production 2.500 Nm3/h 9.379 Tep	**Cogeneration motor** 600 Nm3/h 2.251 Tep	**GNL** 3.784 Tep	**LANDFILL** **32%** Energy recovered
	Leachate dryer 200 Nm3/h 750 Tep	**Fuel-oil** 1.105 Tep	**FACTORY** **100%** Use of fossil fuel **0%** Use of renewable energy source
	Flare 1.700 Nm3/h 6.378 Tep		
PRODUCTION	**FINAL SITUATION**	**FINAL SITUATION**	***FINAL SITUATION***
Biogas production 2.500 Nm3/h 9.379 Tep	**Cogeneration motor** 600 Nm3/h 2.251 Tep	**GNL** 0 Tep	**LANDFILL** **80%** Energy recovered
	Leachate dryer 200 Nm3/h 750 Tep	**Fuel-oil** 837 Tep	**FACTORY** **17%** Use of fossil fuel **83%** Use of renewable energy source
	Flare 500 Nm3/h 1.876 Tep		
	Industrial energy recovery 1.200 Nm3/h	**Landfill biogas** 4.052 Tep	

The project's technological novelty lies in the valorization of the biogas for industrial application. This is summarized in an important reduction in the environmental impacts caused by the activities of the two companies involved in the project, because:

- A highly pollutant gas is valorized at a low cost
- Fossil energy sources are substituted by the landfill biogas as a source of renewable energy

The project's final novelty is that it represents a very interesting sustainable alternative, on both a social and economical level. In this case, a biogas is valorized that has a high content of greenhouse gases. CESPA reduces CO2 emissions by 48%, thereby reducing the environmental impact of its activities, which is part of its sustainable development policy. Also Cerámicas Piera obtains an 83% reduction in the consumption of fossil fuels, thereby reducing the environmental impact of its activities, since it prevents 18,005,040 Kg of CO2 being emitted into the atmosphere each year.

Table 4. CO2 Emissions

LANDFILL				FACTORY	CHANGES
PRODUCTION		PREVIOUS SITUATION			
Biogas production		Cogeneration motor			
2.500	Nm3/h	600	Nm3/h		
4.689	Kg/h CO2	1.125	Kg/h CO2		
		Leachate dryer			
		200	Nm3/h		
		375	Kg/h CO2		
		Flare			
		1.700	Nm3/h		
		3.188	Kg/h CO2		
PRODUCTION		FINAL SITUATION		FINAL SITUATION	*FINAL SITUATION*
Biogas production		Cogeneration motor			LANDFILL
2.500	Nm3/h	600	Nm3/h		**48%** Reduction CO2 emission
4.689	Kg/h CO2	1.125	Kg/h CO2		
		Leachate dryer			FACTORY
		200	Nm3/h		**18.005.040** Kg/year CO2 saved
		375	Kg/h CO2		
		Flare			
		500	Nm3/h		
		938	Kg/h CO2		
		Industrial energy recovery		Landfill biogas	
		1.200	Nm3/h	→	
				2.251	Kg/h CO2

5. CONCLUSIONS

The equipment and systems designed to achieve the energetic valorization of the biogas in a landfill by using it as an energy source in the ceramic factory, were introduced in 2002. Results obtained once the systems has been fully operational, are as follows:

- Energy improvements, which have made it possible to manage the gas effluent generated at the Can Mata landfill site both efficiently and in harmony with the environment. The new set-up means that 80% biogas production can be recovered, as opposed to just 32% that was used beforehand.
- As far as the ceramics factory is concerned, the energy recovery of biogas means that fossil fuels can be replaced by a renewable energy source. The new process design means that with maximum biogas production, 83% of the energy used comes from a renewable energy source, as opposed to 0% beforehand.

- The project's technological development lies in the recovery of biogas for industrial applications, and its immediate effects: a significant reduction in the environmental impact caused by the activities of the two companies involved in the project, which are:
- Energy improvements, which make it possible to manage the gas effluent generated at the Can Mata landfill site in harmony with the environment.
- The energy recovery of the biogas means that fossil fuels can be replaced by a renewable energy source.
- A reduction of 18,005,040 Kg of CO2 in greenhouse gas emissions /year.
- This initiative represents a highly interesting sustainable alternative, from both a social and economic standpoint.