Municipal Solid Waste (MSW) Organic Fraction to Energy. Cuban Case Study. Brief Considerations

Oscar Jiménez Cabeza*, Alfredo Curbelo Alonso, Yoel Suárez Lastre, Jorge L. Aba Medina and Ariel Rodríguez Rosales

Cubaenergia, Centre for the Management of Energy Information, Bioenergy Group, Calle 20 No. 4113 e / 18a y 47, Miramar Playa, Ciudad Habana Cuba

Abstract: This article aims at describing and reports current issues related to the management of MSW organic fraction to energy in Cuba. The paper firstly approach those latest advancements on biochemical based technologies capable of converting MSW organic fraction to energy in a reasonable efficient and economic way, based on analysis of currently widely used biochemical based processes. Lately the paper briefly delves with Cuban previous modest experience in converting solid waste to energy as well as composting residues exiting from already installed bioreactors. Updating of the country's current solid waste to energy facility should be approached in the future.

Keywords: Renewable energy, municipal solid waste, bio-energy, biogas, waste-to-energy.

1. INTRODUCTION

Currently in Cuba a body of laws legislated and established, aiming at properly and efficiently treating and managing municipal solid waste, is rather scarce and incomplete [1, 2]. However few rules and guides have been issues during latest years trying to improve the management and treatment of MSW in the country. Just recently it was clearly stated by the government of Cuba [3], its strong commitment in properly and efficiently solving the problem of the solid waste polluting process and the needs of converting it in power energy and recycling as much as possible of those materials which are valuable for being used later, in order to, not only save energy, but also decreasing the solid wastes which are currently sent to landfilling. The government of Cuba is now prioritizing the efficient handling and treatment of its MSW.

Cuba is now suffering the negative environmental impact of continuous increase and improper handling of MSW mainly in those bigger cities of the country because of:

- The increasing MSW generation index per person.
- Improper waste disposal or scarce sites to disposing MSW.
- Lack of financial resource for properly maintaining the existing poor infrastructure of collecting, transporting and disposing the MSW.
- Lack of MSW processing plant capable of not only recycling/reusing valuable materials but also ensuring the conversion of solid waste to energy.

Considering that roughly little bit over 50% of the country's MSW fraction, is organic, it is of interest to analyze those latest biochemical based technologies capable of properly and efficiently converting this fraction to energy on a sound and reasonable economic basis. On the other hand this paper briefly describes Cuba's previous experience in converting MSW organic fraction to energy, by utilizing anaerobic digestion technology. Additionally MSW to landfill issues in Cuba are also briefly approached.

2. MATERIALS AND METHODS

2.1. Technological Solution General Featuring

In order to precise the technological solution which could best fits to Cuba in terms of its socio-cultural conditions, its economy and financial resource and also taking into consideration those elements of technology transfer, were analyzed several waste-to-energy biochemical based technologies. Their maturity, advantages and disadvantages, international experience, their impact on environment and real possibilities of successfully introducing them in the country, were issues seriously considered.

The list below relates those processes which were studied:

- Wet anaerobic digestion;
- Controlled landfill with biogas capturing;
- Dry anaerobic digestion.

*Address correspondence to this author at the Cubaenergia, Centre for the Management of Energy Information, Bioenergy Group, Calle 20 No. 4113 e/ 18a y 47, Miramar Playa, Ciudad Habana Cuba; Tel: +53 7 2062065;
E-mail: oscar@cubaenergia.cu

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In general terms the suggested biochemical based technological solution should be aiming at ensuring the highest level of solid waste conversion to energy based not only on waste characteristics but also on the financial resource needed to its implementation in the country.

2.2. Anaerobic Biochemical Based Technological Process

2.2.1. Characteristics of the MSW to be Processed

Table **1** shows basic characteristics of the solid waste to be handled (Personal communication).

From Table **1** it is observed that estimated recovery level, mainly for construction/demolition materials is low or non-existence as well as in the case of textiles. This lead that main fraction of rejected solid wastes to landfill will be coming from these wastes along with those unrecovered and unsuitable fraction for energy conversion, whose recovery level is not complete (aluminum, ferrous scrap, glass etc). On the other hand a little bit over 50% of wastes are biodegradable materials, which can be attractive to processing them by using biochemical based principles for obtaining biogas.

2.2.2. Anaerobic Biochemical Based Waste-to-Energy Technological Considerations. Conceptual Approach.

Based on the level of maturity of those biochemical based waste-to-energy technologies and on the real technical, economical and social feasibility of transferring and introducing them to Cuba, as well as, considering on the other hand that over 50% of municipal solid wastes to be processed is organic (biodegradable) waste (food waste from kitchen and tree pruning), it was considered that one of the best option to take into account, is dry anaerobic digestion.

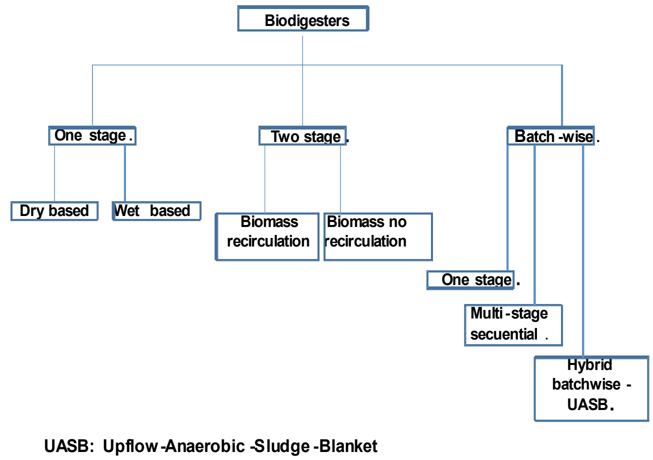

Figure 1: MSW Anaerobic biochemical based technology systems. General classification.

It is worth noticing that biochemical based processes, and those of anaerobic digestion in particular, have been gaining a widespread acceptance for using them in converting biodegradable residues to energy.

Once the highest biodegradable fraction had been processed to biogas, the rest of the fraction, exiting from biodigestor, would be disposed of and sent to a composting process facility.

2.2.2.1. MSW Anaerobic Biochemical Based Technology Systems. General Technological Considerations.

Anaerobic biochemical based technology systems, for treating the MSW organic fraction, can be classified as shown in Figure **1**.

Table 1: Main Characteristics of Solid Waste to be Processed

Solid waste volume to be processed.	350	Ton/d
Process plant operating schedule.	365	days/year
Estimated moisture content of the solid waste.	30	%
Estimated heating value of raw waste.	8075	kJ/kg
Estimated composition of the solid waste %.		Estimated recovery level %
Construction material/Demolition/Debris.	10	6
Paper and cardboard.	9	20
Aluminum.	1	90
Ferrous scrap.	1	90
Plastics.	8	10
Glass.	11	90
Textiles.	1	
Wood wastes (grass, yard waste, tree pruning).	9	
Food wastes (kitchen).	50	
Total	**100**	

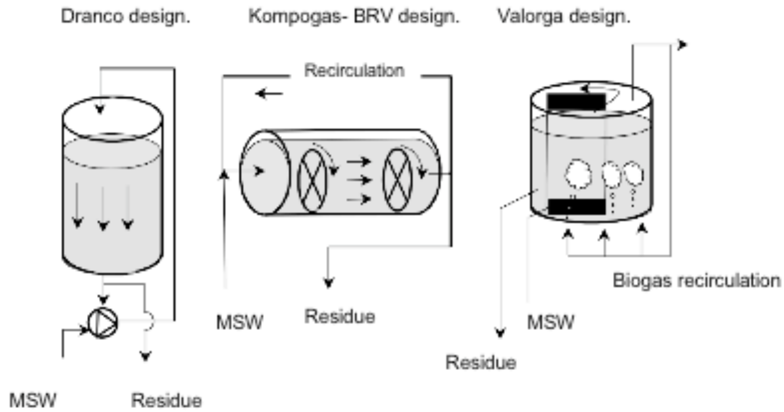

Figure 2: Schematic of one stage commercially proven design dry anaerobic digesters for treating MSW.

From the commercial point of view and considering reliability of their operation, the most widely used biochemical based technology, specifically in Europe, is one stage dry anaerobic digestion technology. This technology has demonstrated to be highly reliable on commercial basis in Germany and France [4].

Figure **2** schematically shows several commercial designs of those mentioned above biochemical based technology.

A typical featuring of these systems is their plug-flow flux pattern, due to the viscosity of the digested residue which has to be moved inside the digester in opposite to the wet anaerobic digester technology, where continue stirred tank reactors (CSTR) are used.

Those systems that utilize wet anaerobic digestion, in this category, have the disadvantage of consuming an important amount of water (1m^3/Ton., MSW), to adjusting the total solid concentration in the digesters. On the other hand, those bioreactors featuring dry anaerobic digestion process, consume 10 times less water when compared with the previous one [4].

The two stages systems, on the other hand, were conceptually designed for favoring the MSW biochemical treatment in separate process for ensuring an optimized operation of each one of them. These systems are rather more complex and costly than their one stage counterpart, leading to a limited use of them on commercial basis. At the same time the introduction of biomass recirculation has the main objective of improving the biochemical transformation process of the MSW, so increasing the amount of living cells in the bioreactor favoring the methane producing kinetics, which are developed in the second stage of these systems. A simplified schematic layout is shown in Figure **3**.

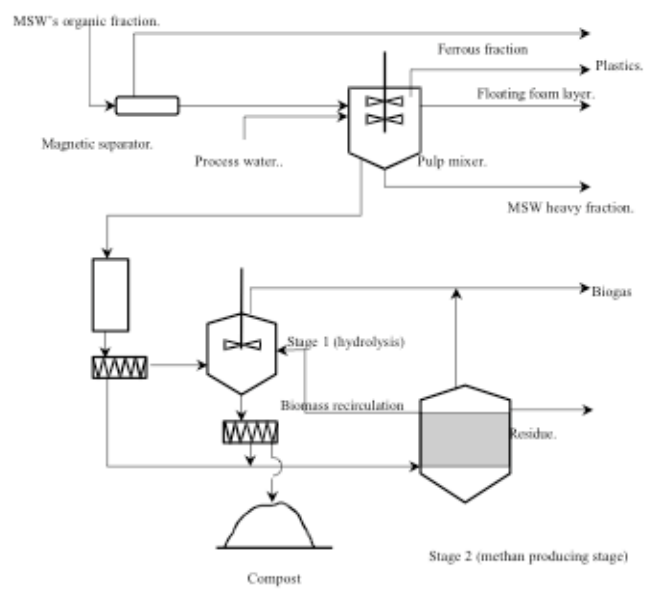

Figure 3: MSW two stage wet anaerobic digestion system with biomass recirculation.

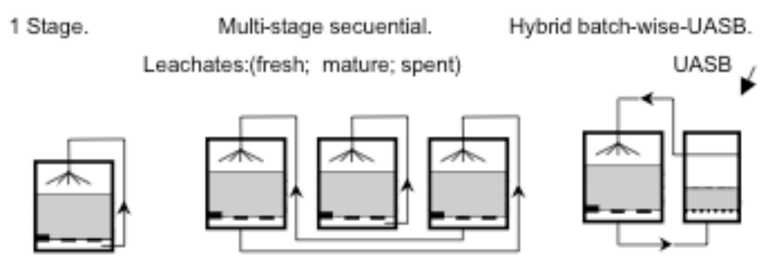

Figure 4: MSW leachates re-circulating patterns commercially used in batch-wise anaerobic digesters.

Batch-wise bioreactors are fed discontinuously, as their names imply. Once the batch is introduced the system is closed letting the biochemical transformation to proceed. The leachates exiting from bioreactors are re-circulated under different patterns [4]. Schematic representation is shown in Figure **4**.

Figure 5: Batch-wise dry anaerobic bioreactors for treating MSW organic fraction.

Batch-wise bioreactors are technically not complex systems. They are roughly 40% less costly when compared to their flow-systems counterpart. However the land area for their installation is considerable higher. Typically they are an attractive technological option in underdevelopment countries. Commercially proven systems have demonstrated that the limiting factor for their implementation is the investment cost. Figure **5** shows a photograph of these systems.

2.2.3. Cuba's Previous Experience in Transforming MSW Organic Fraction to Energy

In 2009 a rather small MSW organic fraction-to-energy facility was installed. The funding for materializing this experience was provided by a UNDP funded project along with a Swedish government budget. Figure **6** shows several photos taken at the facility.

The design plant's capacity is 2700 ton/year. The organic solid waste comes mainly from households and agro-markets. Before feeding the collected waste to the plant a sorting and screening process is achieved in order to ensure a contaminant free material.

The facility is capable of producing 432000kWh/year. At the same time, residue coming from biodigester is sent to a nearby composting facility.

The composting plant, using the windrow composting system, was designed to produce 4000

1. Organic fraction feedstock.

2. Facility´s Control room

3. Facility's front view.

Figure 6: Facility's photos showing its control room, feedstock and biodigester.

1. Front loader for windrow turning. 2. Windrow composting system.

Figure 7:

ton/year with 30% humidity, and was sought to operate roughly 230 days/year. Figure **7** shows photos of the windrow as well as front loader used for windrow turning.

Currently the facility needs up-grading in order to achieve a sound and steady work in converting MSW organic fraction to energy.

Also, as part of Cuba's previous experience in converting MSW organic fraction to energy, an old landfill was upgraded in 2009 in order to capturing the biogas generated for power generation. The facility was only capable of capturing the biogas and flaring it but, due to lack of financial resource, it was not possible to generate power. The facility was partially funded by Cuban government. According to preliminary estimates, the upgraded landfill was capable of reducing emission to the atmosphere in 3.757.334 ton., CO_2 equivalent in a period of roughly nine years.

Currently this landfill is about to end its exploiting period and should be shut down due to waste overloading which explain the government concern and its interest in starting a MSW-to-energy conceptual design. A paper, briefly describing it, was published last year [5]. Figure **8** shows different photos during facility setting-up at that moment.

1. Landfill drilling

2. Biogas capturing well installed.

3. Torch system for flaring biogas.

Figure 8: Photos showing moments during facility setting-up.

2.2.4. Environmental Issues Consideration

Among those critical environmental problems which are currently facing those bigger cities world-wide are:

- Water and air pollution.
- Environmental noise.
- Solid wastes accumulation and disposal.

Cuban bigger cities are not free from those mentioned above problems, where solid wastes accumulation and improper wastes disposal are currently playing an important role.

Waste recycling has been a point of utmost interest to Cuban government even though only really small and highly modest experience had been achieved so far.

As a reference, The North America Environment Protection Agency [6], estimates that through recycling one ton of cans, made of aluminum; it could lead to the saving of energy amounting (218.4 million kJ/ton), with the corresponding decrease of Green House Gases (GHG) representing an equivalent amount of 7.46 metric ton of carbon equivalent/ton waste, which otherwise would be sent to environment.

Preliminary estimates, developed for the Cuban case study leads to the following estimates:

- Total metric ton., of carbon equivalent not emitted to atmosphere/year: 30183.
- Total metric ton., of fossil fuel equivalent not consumed/year: 19750.

Additionally, estimated amount of solid wastes avoided to landfill should be around to 311 ton/day containing mainly construction material/demolition/debris due to the lowest recovery level expected for this waste in the front-end solid processing, as well as those others unrecovered and unsuitable fraction for energy conversion.

3. CONCLUSION

- MSW characteristics and composition play an important role at defining the anaerobic biochemical based technology system to be introduced to converting solid waste to energy.
- In the present case, because over 50% of the solid waste processed is organic, biochemical based technology was sought to be a proper choice for treating such waste to energy (biogas).
- Existing facility needs upgrading in order to achieve a sound and steady work in converting MSW organic fraction to energy.
- Study and assessment of those latest advancements on anaerobic biochemical based technologies capable of converting MSW organic fraction to energy in a reasonable efficient and economic way, can help in finding the best choice for the Cuban case.

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