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Combined use of biogas from sanitary landfill and wastewater treatment plants for distributed energy generation in Brazil

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ABSTRACT

Biogas is a fuel which has a high potential energy and it is produced from the anaerobic degradation of organic material. It can be used for many applications such as heat and electrical generation and fueling vehicles. Given that anaerobic reactors and landfills are the main forms for treating domestic solid waste in Brazil, this current article presents a five scenario analysis on the energy potential and economic viability of the combined use of biogas produced in these structures for generating electricity in the city of Itajubá, Brazil. From the energy point of view, the best case scenario is the combined use of biogas from sanitary landfill and sewage treatment station. This scenario resulted in an installed power of 685 kW, with an annual energy production capable of supplying approximately 10% of the city's energy. Concerning the economic aspect, the best option is the use of biogas from sanitary landfill in an isolated manner, due to the shorter distance of the transport of the gas, in comparison with other scenarios. The results demonstrate the potential and possibility of economic viability for the use of biogas in urban structures for these microregions in Brazil, indicating that the development of biogas use in small cities can be accomplished within the resolutions of distributed microgeneration. Such potential tends to increase as basic sanitation grows throughout the country.

1. Introduction

The necessity to reduce greenhouse gas emissions has increased the interest in biogas as a green fuel (Sigot et al., 2014). Biogas is identified as a renewable energy fuel which aims to reduce the use of fossil fuels, aside from promoting sustainable energy and decentralizing a country's energy generation (Roya, 2012). As a tropical country, Brazil has enormous potential for energy production due to its vegetation biomass. Furthermore, as a highly populated country, there are opportunities for high energy production from domestic, industrial and agro-industrial activities (Coldebella et al., 2006). These waste products (solid waste and domestic effluents, agro-industrial wastes, etc.) are important raw material for the production of biogas when submitted to anaerobic digestion.

The average composition of biogas varies due to the characteristics of the waste and conditions of the digestion process. According to Leonzio (2016), generally the composition is approximately 55% - 70% methane in volume (CH_4), 30% - 45% carbon dioxide (CO_2), aside from 80-100 ppmV of ammonia (NH_3), 1000-3000 ppmV sulfuric acid (H_2S) and hydrocarbon (< 100 ppmV). Traces of siloxanes can also be found in biogas. The use of biogas as an energy resource is mainly due to the presence of methane (CH_4), which can be used in multiple applications, such as the generation of thermal and electrical energy, fueling cars, injection into natural gas networks, among others (AEBIOM, 2009; PROBIOGÁS, 2010).

In any urban city, two important waste materials are constantly generated and can be used to produce biogas: Urban Solid Waste (USW) and domestic effluents. The main disposal points for USW in Brazil are landfills (ABRELPE, 2016) and the main treatment point for domestic effluents are anaerobic reactors (National Water Agency – ANA, 2015). In both landfills and anaerobic reactors, anaerobic digestion happens during the processing of organic material and biogas production. Approximately 2,200 Brazilian cities already have landfills (MMA, 2014). A population of approximately 19 million inhabitants has its treated

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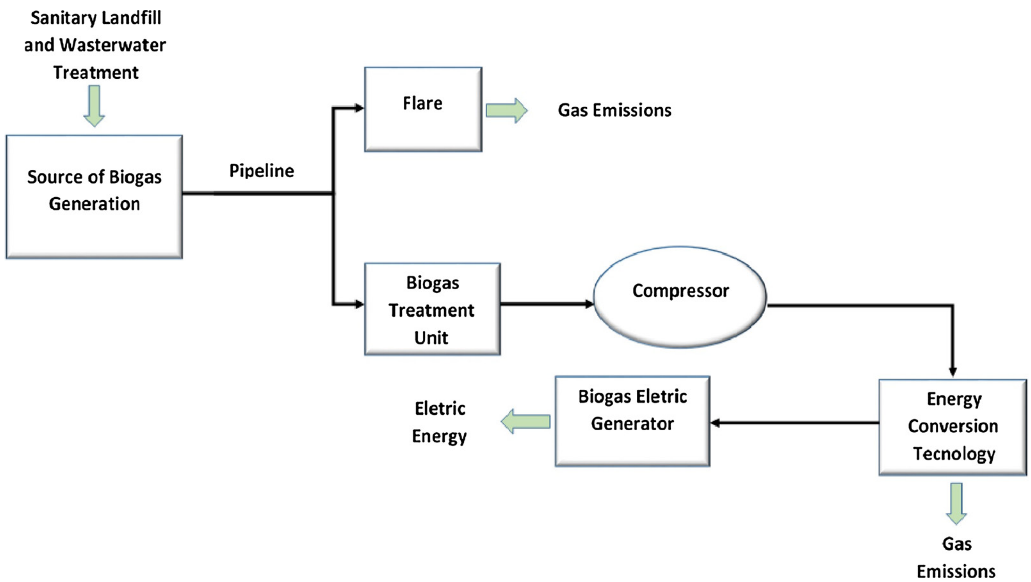

Fig. 1. Diagram of a thermo-electric plant powered by biogas.

sewage by processes which involve anaerobic reactors (National Water Agency – ANA, 2015). With the production of biogas in these structures, an opportunity arises for energy generation.

According to the São Paulo State Environmental Company (CETESB, 2006), in order to implement biogas electrical energy generation, the following minimum components are necessary: i) gas holder, or gasometer: to store the collected gas; ii) compressor: to pump the gas; iii) pipes: to capture and transport the collected gas; iv) Flare: to burn off unutilized gas converting CH_4 into CO_2 in order to reduce global warming impacts; and v) equipment for energy conversion: multiple technologies can be adopted. Treatment units could also be installed in order to remove the gas impurities and increase methane content. Fig. 1 presents a diagram of a thermo-electric plant powered by biogas.

The Brazilian National Solid Waste Policy (BRAZIL, 2010) aims to put an end to dumps in the country through incentives which are environmentally suitable for waste disposal. The reflex of this law has been a considerable increase in sanitary landfills, since this is the cheapest alternative after dumps (Agamuthu, 2013). According to the Brazilian Association of Public Companies (ABRELPE, 2016), urban solid waste disposal in sanitary landfills grew from 113,975 tons/day to 116,631 from 2014 to 2015. Currently, about 60% of municipal solid waste (MSW) produced in Brazil is destined for sanitary landfills. The remaining MSW is usually sent to landfills, with failures in the system for the leachate treatment or gas collection (called controlled landfills or open dumps) (ABRELPE, 2016).

Santos (2015) provides a research on the panorama of energy from landfills in Brazil. According to the author, based on the current scenario in which the number of sanitary landfills is increasing, the use of landfill Gas (LFG) becomes an excellent option for decentralized generation. This option is favored by the fact that the sanitary landfills are generally located at close distances from solid waste generating centers. The implementation of urban solid waste energy generation, meeting environmental legislation, is one of the goals for the Brazilian solid waste policy (BRAZIL, 2010).

Santos et al. (2018a) calculated the energy potential of biogas plants in Brazil. According to the authors, the electric potential of biogas plants in Brazil is 7 GW (approximately 5% of the Brazilian electricity matrix), and 24.6% of this potential is concentrated in sanitary landfills. Sisani et al. (2016) analyzed a landfill in Italy and obtained an average potential energy production of 43 kW h per ton of waste. Li et al. (2015) analyzed the incentives for landfill gas energy generation projects between 1991 and 2010 in the USA and concluded that these incentive projects contributed to the reduction of 10.4 $MtCO_{2eq}$ during the studied period. This data demonstrates how the generation of energy from biogas in landfills can be effective in assisting the rising of clean energy generation and reduction of greenhouse gas emissions in a country.

With regard to sewage treatment plants in Brazil, the rate of sewer treatment in 2015 was 42.67% (Trata Brazil Intitute, 2017). The national goal, established in the National Sanitation plan, which goes until 2023, is for 85% of urban municipalities to have sewer collection networks and 77% of all sewage treated (PLANSAB, 2013), indicating a growth tendency in the number of wastewater treatment plants (WWTP) throughout the country. With this growth, there is an opportunity for Brazil to plan future WWTPs, which encompass biogas electricity generation (Santos et al., 2016a). The energy generated can be used to power the WWTP itself, diminishing wastewater treatment costs and increasing the economic viability of the operation as a whole. A biogas power plant that operates with biogas produced in an anaerobic reactor, treating domestic effluents in Brazil, is capable of generating 1.4 W/inhabitant (Santos et al., 2016b). According to Santos et al. (2016b), the energy produced at WWTPs containing anaerobic reactors as upflow anaerobic sludge blanket (UASB) with post-treatments can, on average, supply at least 59% of the energy consumed in the course of the sewage treatment.

Santos et al. (2016a) and Barros et al. (2014) calculated the electrical power present in anaerobic WWTPs and landfills in Brazil. According to Santos et al. (2016a), the maximum economically viable electrical power using anaerobic WWTP generation could reach 1 TW h in Brazil by 2040. In the same study, the minimum population contributing domestic effluents to a WWTP to make the project economically viable is 300,000 inhabitants. Barros et al. (2014) performed calculations for landfills and obtained the minimum population to make landfill energy generation viable is 200,000, and the maximum potential economically viable is near 4 TW h in the most favorable scenarios by 2030. The minimum viable population for the projects demonstrates that the economic feasibility is a limiting factor for the development of biogas plants in Brazil.

In Brazil, the electrical energy consumption of sanitation in 2016 was close to 14 TW h/y (Moreno, 2017), without considering the fuel consumption of trucks transporters of waste to landfill. Therefore, the use of the potential identified by the aforementioned studies in anaerobic WWTPs and landfills (which surpasses 5 TW h) will significantly decrease the energy balance of the sanitation sector in Brazil. The total expenditure of the sanitation service providers, with electrical energy in