Renewable and Sustainable Energy Reviews 48 (2015) 300–305

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

# Exploring possibilities of energy insertion from vinasse biogas in the energy matrix of Paraná State, Brazil

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ARTICLE INFO

*Article history:*
Received 28 August 2014
Received in revised form
2 February 2015
Accepted 3 April 2015

*Keywords:*
Vinasse
Energy
Technical–economic assessment

ABSTRACT

The growth in the sugar and alcohol sector in Brazil has led to a significant increase in vinasse production, what aggravates the issue of its destination. Anaerobic biodigestion is an alternative for the treatment of this byproduct, presenting a relevant economic factor: its use as a source of energy. This work presents a technical–economic assessment of the electric energy production from vinasse biogas, obtained from an alcohol plant located in the state of Paraná, Brazil, under three different operations. For each operation, it was considered five scenarios, varying from the most optimistic (best energy selling price) to the most pessimistic (worst energy selling price). The viability of the proposed project was calculated by using the Internal Rate of Return (IRR), Net Present Value (NPV) and Discounted Payback Period (DPP), showing that the plant is feasible for almost all scenarios. The energy production costs for the expected scenario for Operations 1, 2 and 3, were US$ 38.91 MW h$^{-1}$, US$ 56.32 MW h$^{-1}$ and US$ 46.93 MW h$^{-1}$, respectively.



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## 1. Introduction

The use of non-renewable sources for energy production and their environmental implications has stimulated the development of alternative technologies for energy supply. According to Halder, Paul and Beg [1], the use of biomass for energy production increased significantly during 2010 in many European countries, United States, China, India and some other developing countries. Yet, it is estimated that the capacity of power generation from biomass in 2012 was 83 GW – 12% higher than 2011.

According to Silva [2], biomass is considered a renewable energy source, because its replacement in nature can be made without great difficulties, in just a few years or even less, unlike fossil fuels, which demand thousands of years and favorable conditions.

According to Salomon and Lora [3], the production of energy with the use of biogas from municipal solid waste (MSW) landfills, waste treatment plants, vinasse biodigestion (sugarcane residues) and anaerobic biodigestion of animal manure have long been discussed in Brazil, as well as the improvement in the handling of these residues.

Holm-Nielsen, Al Seadi and Oleskowicz-Popiel [4] state that biogas can be used in many ways and indicate their main forms of use

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http://dx.doi.org/10.1016/j.rser.2015.04.023
1364-0321/

as: (i) production of heat or steam; (ii) production of electricity through co-generation; (iii) industrial energy source to heat, steam, electricity and cooling; (iv) use as automotive fuel; (v) production of chemicals; (vi) injection in natural gas networks; and (vii) CAC fuel (fuel cells).

Despite the many possible uses, currently biogas is mainly used for electricity generation (about 2/3rd of the total amount, half obtained in co-generation plants) and heat production (1/3rd remaining) [5].

The sugar and ethanol industry in Brazil is in process of expansion. In 2010, there was an increase of 7.1% in comparison to 2009 [6]. According to Pinto [7], the Brazilian sugarcane industry has a strong influence on the energetic, social and economic scenario of the country. It is also a promising alternative for the replacement of fossil fuels.

The production of sugar and ethanol, according to Silva et al. [8], generates two main types of waste: agricultural residues and industrial byproducts. The first group is composed mainly of the straw that is burned or crushed in the harvesting process. The second group generates five main types of waste or byproducts – ash, bagasse, filter cake, molasses and vinasse. Most of these residues present a high content of organic matter, which can become a potential source of energy when treated properly [9,10].

In that sense, there is a great potential for electric energy generation from byproducts of the sugar and alcohol industry. Thus, there are many studies and researches on the use of sugarcane bagasse in animal nourishment and even its use in boilers and the application of vinasse as a fertilizer. According to Granato and Silva [11], the burning of vinasse can activate gas turbines, providing electric energy. However, according to Monteiro [12], the large amount of vinasse resulted from increasing ethanol production has brought some environmental problems by presenting a highly polluting potential.

In this scenario, the anaerobic digestion of vinasse is an alternative treatment for this byproduct, also presenting an important economic consequence: the production of methane and its use as an energy source [13].

In the Brazilian state of Paraná, sugar and alcohol plants are located in the northern and northwestern regions, and ethanol production in the 2009/2010 harvest was 1,885,121 $m^3$, equivalent to 6.7% of the national production, which was 27,962,558 $m^3$ [14]. Vinasse produced from these sugar and alcohol factories could have been used to produce biogas and generate an additional amount of electricity, since, coincidentally, the harvest period in which one can have bagasse and vinasse corresponds to the dry season of water generation. In other words, there are complementary sources.

Thus, this study presents a technical and economic assessment of the production of electricity from vinasse biogas obtained from a sugar and alcohol plant in the state of Paraná, Brazil. This electricity will be sold to the local energy supplier (COPEL – Energy Company of Paraná State).

## 2. Biodigestion of vinasse

Almança [15] states that vinasse is considered an aqueous form (suspension) of organic and mineral solids as components of the distillation wine, which contains residual amounts of sugar, alcohol and volatile components.

Vinasse composition can vary widely throughout the day, year and variety. It is rich in nutrients such as potassium, calcium and sulfur, in addition to presenting high content of organic matter and a pH ranging from 3.7 to 5. Because of these characteristics, and for presenting a relatively low cost, the vinasse has been widely used in fertirrigation of areas cultivated with sugarcane [16,17].

In Brazil, in the 2011/2012 crop year, about 300 billion gallons of this waste were produced [18], considering an average of 13 l of vinasse for every liter of ethanol produced. This value, however, can reach up to 20 l, depending on the type of feedstock and the level of technology used in the fermentation [19–21].

Launched in soils adjacent to the plants, as fertilizer for exploitation of minerals, its use has many benefits such as increased productivity, improved soil physical conditions, return nutrients to the soil, among others [22,23].

However, one should use it with caution, since it may contaminate groundwater and surface water sources, due to percolation or drag of high concentrations of manganese, iron, potassium, aluminum, chloride, organic matter, among others [24].

According to Salomon et al. [25], the anaerobic digestion consists in the fermentation process of organic waste, producing methane and carbon dioxide, which are the main components of biogas. The efficiency of digestion depends on specific operating conditions, such as the process temperature and pH, type of substrate used, solids concentration and retention time of biomass in the digester [26,27].

According to Granato [28], the biogas from anaerobic digestion of vinasse can be exploited in the following ways: i) Burning it completely in the boiler, generating steam to operate the entire mechanism to crush sugar cane. In this case, studies show that there exists a surplus of 25–28% of all bagasse that is usually burned in boilers and could be used for other purposes; ii) One third of the biogas could be purified, producing methane to replace all fuels used in the agricultural industry during the harvest, and the remaining two-thirds would be burned in boilers providing a surplus of 18% of bagasse; iii) The total biogas could trigger a gas turbine coupled to an electric generator, producing 2.5 times the total electricity needs for an autonomous distillery.

The use of vinasse through the digestion is presented as a promising scenario, since one of the byproducts of the digestion process, methane ($CH_4$), is produced in sufficient quantity to generate electricity.

## 3. “Plug-Flow” biodigestor

According to Lima [29], the tubular flow reactor anaerobic model, also called “plug-flow“ (Fig. 1), is a continuous feed reactor, characterized as a covered rectangular pond (length/width ratio in the order of 3:1).

It is basically characterized by a fermentation chamber dug in the soil, covered with a blanket of High Density Polyethylene (HDPE), with a thickness of 0.8 mm to 2 mm, black in color. The inner liner is made of flexible synthetic material, blanket Polyvinyl Chloride (PVC), with a thickness of 0.8–1 mm, in black or white colors, used to prevent leakage, contamination of soil and groundwater [29].

According to the same author, the cover with blanket flexible PVC acts as a gasometer (balloon), storing biogas and avoiding their emission to the atmosphere. When the gasometer is inflated, the biogas pressure will remain constant due to the flexibility of

**Fig. 1.** “Plug Flow” anaerobic reactor.