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Electricity generation from biogas of anaerobic wastewater treatment plants in Brazil: an assessment of feasibility and potential

Ivan Felipe Silva dos Santos*, Regina Mambeli Barros [1], Geraldo Lucio Tiago Filho [2]

Natural Resources Institute (IRN), GEER, Renewable Energy Group, UNIFEI (MG), Av, BPS, 1303, Itajubá, MG, CEP: 37500-903, Brazil

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ABSTRACT

Electricity production is essential for development, but it is necessary to reduce fossil fuel use and greenhouse gas emissions. Alternative energy sources are thus needed, especially renewable ones. In this context, biogas from anaerobic digestion becomes an important renewable fuel that is excellent for distributed generation. This study presents a concise method for analyzing the economic viability and energetic potential of energy generation by biogas from anaerobic wastewater treatment plants. This method could be replicated with any municipal solid waste (MSW) connected to a population. We evaluated the contributing population size that is necessary for the financial viability of installing such a plant to generate electricity in Brazil. Population and energy consumption projections in Brazil were used to analyze the maximum production potential of these power plants. The results indicate economic viability for only cities with population greater than 300,000 and that the energy potential could supply nearly 0.25% of the residual fuels according to the Brazilian Ministry of Science and Technology. This energy potential consists of all the energy that could be produced by waste in Brazil by 2020, such as sugar cane bagasse and agroforestry residues. Such power plants could produce about 1 [TWh] of electricity by the year 2040. This energy potential could become higher if these plants became viable for smaller populations, which indicates a need for public policies regarding the feasibility of biogas plant projects in Brazil.

1. Introduction

Increases in global energy demand, limited fossil fuels reserves, and the need to reduce greenhouse gas emissions (GHG) have led to increased interest in renewable energy production. Worldwide, Brazil has a prominent position regarding the use of renewable energy sources. For example, according to the National Energy Balance (BEN, 2013), the portion of renewable energy comprising the Brazilian energy matrix in 2012 remained much higher than average and was in fact among the highest in the world. In Brazil, the latest data from the National Information System on Sanitation (SNIS) indicated growth between 2010 and 2011 in both the percentage of collected sewage and urban sewage that is treated (from 68.2 to 68.8% and 53.5–55.5%, respectively). Biogas is produced from anaerobic digestion of the effluents in sewage treatment and could be used to generate renewable power.

Untreated domestic sewage causes severe ecological harm by polluting both ground and surface water, and it is thus important to dispose of it safely (Elango et al., 2007). This leads to a need for wastewater treatment plants (WWTPs). The best technique for treating sewage varies with the characteristics of cities, such as climate, topography, wastewater pollution, land prices, and other factors (Nuvolari, 2003). Activated sludge systems and anaerobic reactors are among the methods most used for domestic sewage treatment. The technologies used for sewage treatment in Brazil are listed in Table 1, where a predominance of anaerobic treatment can be seen.

According to Von Sperling (2002), activated sludge systems are most often used in large wastewater treatment plants in situations where the effluent should be of high quality and there is limited space. In activated sludge systems, anaerobic digestion of the sludge produces biogas. One type of reactor used in these systems is the upflow anaerobic sludge blanket (UASB). According to Chernicharo (2007), the sewage flows upward in these reactors

* Corresponding author. Tel.: +55 (35) 84663595.
E-mail addresses: ivanfelipedeice@hotmail.com (I.F.S. Santos), remambeli@hotmail.com (R.M. Barros), tiagounifei@hotmail.com (G.L. Tiago Filho).
[1] Tel.: +55 (35) 36291224.
[2] Tel.: +55 (35) 3629 1156.

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Table 1
Total number of municipalities, number of municipalities with sewage treatment available, and type of treatment system used in 2008. Source: IBGE (2008).

Overall total of municipalities	5564
Total	1513
Biological filter	317
Activated sludge	27
Anaerobic reactor	188
Oxidation valo	565
Anaerobic pond	431
Aerobic pond	131
Aerated pond	93
Facultative pond	672
Mixed pond	65
Maturation pond	238
Wetland/soil application, water plants	20
Septic tank condominium system	109
Other	129

through a dense bed in which there is high microbiological activity. The methods of recovering biogas from both of these systems are shown in Fig. 1.

Besides being simple to construct and having low operating costs, the anaerobic reactors can with stand high organic loads and simultaneously produce biogas that is rich in methane (CH_4) as a by-product (Campos, 1999). Their efficiency for removing organic components ranges from 60 to 70%. These anaerobic reactors can also be used to preprocess waste sent for an activated sludge treatment system, thus reducing implementation costs, energy consumption, and other expenses (Table 2). Biogas production is facilitated by the effluent treatment and occurs in phase with it. In an anaerobic reactor, biogas production does not require the transport of sewage sludge to biodigesters or the construction of biodigesters, in contrast to activated sludge systems (Fig. 1).

According to Moreira (2014), 35% of WWTPs in Brazil are supported by the Brazilian Growth Acceleration Plan, including the anaerobic reactors that are part of this project, and 64% of existing WWTPs in Brazil have anaerobic primary treatment. This demonstrates the importance of anaerobic treatment for Brazil. According to Torres (2012), Latin America has a higher level of sewage treatment by anaerobic environments, which is a very important technique for this region due to the local temperature (usually exceeding 20 °C). This treatment method produces by-products such as agriculture nutrients and offers the possibility of bioenergy production.

Biogas is a promising renewable fuel that can be produced from a variety of organic raw materials and provide energy for various uses (Lantz et al., 2007). Typical components and percentages of this are shown in Table 3. Thus, treatments are applied to purify the gas in order to increase its calorific value, and the degree of purity depends on the intended use. The resulting biogas can then be used for lighting, heating, network supply, vehicle power supply, boilers, co-generation processes, and the generation of electricity (Jordão and Pessoa, 1995; Appels et al., 2008).

Although anaerobic digestion is a mature and well-established method for methane production (and therefore energy), there are emerging technologies that could compete with the production of biogas in the future, such as bio-hydrogen production. According to Azwar et al. (2014), hydrogen is one of the major candidates that can enable the transition from an economy based on fossil fuels to one based on renewable energy. This hydrogen production can be performed using different processes, substrates and bioreactors. Bakonyi et al. (2014) reviewed experiences with starting biohydrogen production in bioreactors and created an extensive list of several studies regarding the departure of biohydrogen production under various conditions.

According to Shen et al. (2015), biogas can produce sustainable energy for WWTP and help to reduce fossil fuel demand and GHG emissions. However, much of the biogas produced in WWTPs in the USA is burned in flares, and only a small part is used for heat or energy production. This is also true in Brazil, where bioenergy production is still incipient and limited to a small number of plants. In contrast, more than 800 WWTPs in Germany use biogas to

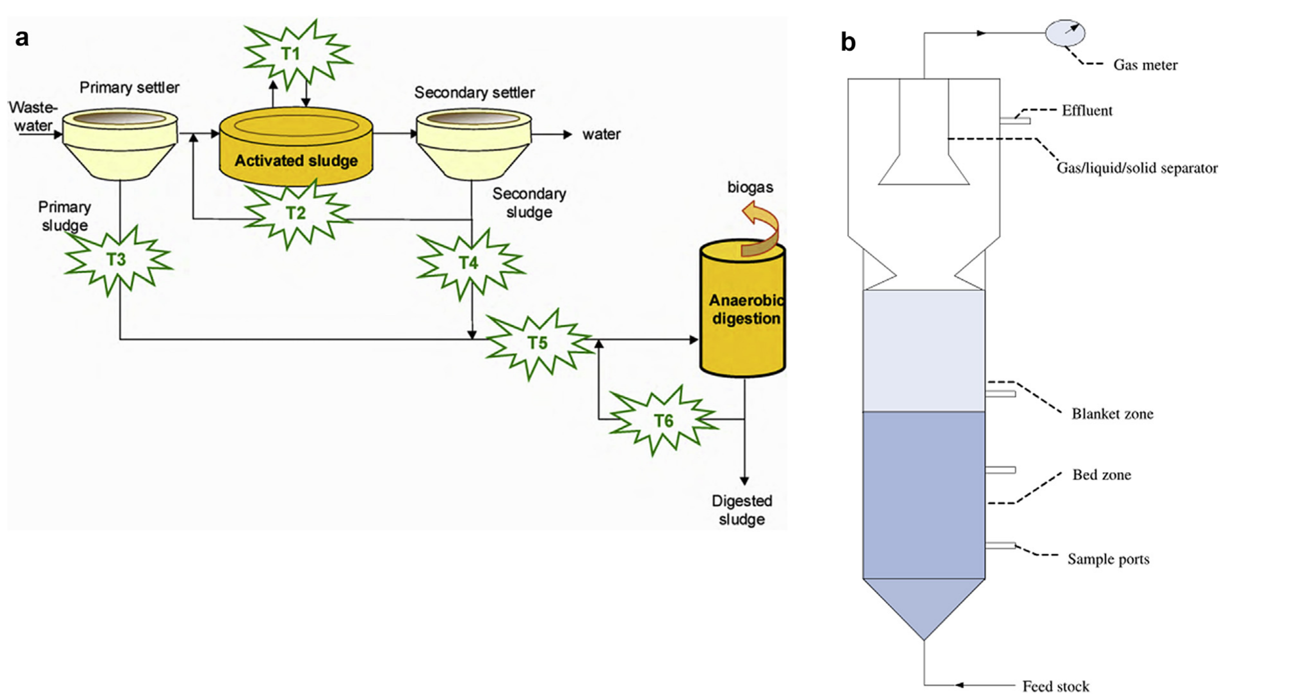

Fig. 1. (a) Activated sludge system with posterior sludge digestion for biogas production and (b) UASB reactor. Source: modified from Carrère et al. (2010) and Wang et al. (2007).