The perspectives of biomethane to contribute to increase the NG supply

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Abstract

The Bioenergy Research Group of the Institute of Energy and Environment at the University of São Paulo (GBIO / IEE / USP) is developing the "Project 27 - The biomethane contribution prospects to increase the supply of natural gas in São Paulo" - within the Research Center for Innovation in Natural Gas (RCGI). This is a center of advanced studies on sustainable use of gas, created at USP with funding from FAPESP / Shell / BG. This Project 27 will map the production of biogas and biomethane from vinasse, animal residues (livestock waste and residues from slaughterhouses) and urban residues (solid wastes and liquid effluents). It is important to mention that, besides the use of biogas for energy production, there is another option. After the upgrading process of biogas (CO2 and impurities removal), biomethane can be used as a primary source of energy to be fed into NG pipelines and be distributed to different consumers, as well as in the form of CNG when necessary. Also, in the case of biomethane from vinasse, it can be used to fuel the sugar mills' diesel fleet (trucks and agricultural equipment). During the development of Project 27, financial, technical, environmental and social aspects of production and use of biomethane will be analyzed. These aspects will be addressed as important points to encourage the biomethane market in São Paulo, such as the need to consider the fundamental synergy between biogas for energy generation and basic sanitation. In view of the above, this article aims to present Project 27, as well as the preliminary results obtained so far.

Keywords: biogas, biomethane, urban waste, agro-industrial waste, energy potential.

1. Introduction

Biogas is the gas mixture produced by the process of anaerobic digestion of organic residues, mainly from organic waste in landfills, sewage treatment stations, animal residues and agro industries, where biogas from vinasse presents significant perspectives. Biogas composition is mainly methane (CH4) and carbon dioxide (CO_2), as well as other compounds such as water H_2S and other impurities (in the case of biogas from landfills and sewage stations there is also the presence of the so-called siloxanes, compounds produced from shaving cream, toothpaste, and other products).

Biomethane is the methane extracted from biogas in a purification process, as discussed ahead, eliminating the impurities including carbon dioxide. It is mainly methane and the denomination biomethane is used to call the attention to its renewable origin. Biogas and biomethane can be used for different energy purposes: for electricity production, for thermal purposes, replacing conventional fossil fuels in vehicles and also to be injected in natural gas grids.

Biogas can be used for decentralized power generation with combined heat and power - CHP (cogeneration) systems and electricity surplus can be injected into the interlinked grid or sold for other consumers. Biomethane can be used as the diesel replacement in agricultural equipment (tractors, trucks, etc.) or to be injected into the natural gas grid. Biogas can also be used for cooking, as in many countries, but this option is not feasible in Brazil and it was not analysed in this article, since in Brazil there is the LPG (liquefied petroleum gas) network used for cooking with large success and special programs to distribute it.

The use of biogas and biomethane as an energy source can contribute to make feasible the achievement of existing climate policies in Sao Paulo State and in Brazil. It is important to remark that the INDC Intended Nationally Determined Contribution), signed by Brazil in the context of the Paris Agreement, has just been ratified on September 12, 2016 by Brazilian Federal Government. This means that there are goals to be achieved by Brazil related to C emissions:

- By 2025: reduction of 37% compared to 2005.
- By 2030: reduction of 43% compared to 2005.
- Increase the share of biofuels in the Brazilian Energy Matrix up to 18% by 2030.

Considering that the emissions from the Brazilian energy matrix have been increasing significantly due to the use of thermoelectric power plants using fossil fuels and to the increase of gasoline consumption due to the reduction on ethanol offer (due to gasoline price control by Federal Government in 2014).

In several states, there are already legislations to incentivize the injection of biomethane into the gas grid: Sao Paulo State: Decree N. 58,659 from Dec 4, 2012; Rio de Janeiro State: Law N. 6,361 from Dec 19, 2012; Espirito Santo State: Decree 3453-R from Dec 2013; and Rio Grande do Sul State: Law N. 14,864 from May 2016.

All these legislations must follow the rules from the National Regulatory Agency on Oil, Gas and Biofuels; the Agency defined the rules on its Technical Note N. 157.2014 SBQ RJ, from Sep 17, 2014, where biomethane injection into natural gas grid is allowed only if is not produced from landfills t and sewage stations. The reason pointed for this decision is the fear of the presence of siloxanes (even after the cleaning process), since these are dangerous contaminants. It seems there is a lack of enough knowledge on the existing cleaning processes.

In Europe, natural gas is used mostly to provide electricity and heat and as fuel in industrial processes (Eurostat, 2014). One important aspect of using natural gas is the fact that it produces less CO2 per KWh than other fossil fuels, such as coal and oil (US EIA, 2016); however it is not carbon neutral. Furthermore, natural gas is responsible for about 24 per cent of European energy consumption and the issue of energy security arises as natural gas is not distributed evenly between countries (Statista, 2015).

An alternative to natural gas is biogas. To be able to use biogas in machinery designed to run on natural gas it must be upgraded into biomethane.

Whilst biomethane can be utilised as a transport fuel and in electricity generation, some studies (Lantz et. al., 2007) have concluded that injecting biomethane into the natural gas grid would result in full use of the gas produced. Whilst biomethane is seen as a solution to climate change, it has yet to see full utilisation across Europe. This is due to technical, political and economic barriers and there is very little in the literature regarding the barriers facing injection.

As the rest of the world looks to learn from Europe on the use of renewable energy, the lack of information about barriers facing biogas use could be preventing the injection of biomethane into the natural gas grid globally; this is the key driver for this study.

In this context, this article aims to present the project 27 - The perspectives of biomethane to contribute to increase the NG supply, in the scope of the Research Centre for Gas Innovation (RCGI) of the University of São Paulo. The scope of the Project 27 is to analyze the perspectives, the corresponding benefits and potential barriers, as well as proposing adequate policies for integrated solutions using biomethane as a contributor to the offer of natural gas (NG). The aim is to analyze the contribution of those solutions to increase the offer of both biomethane and natural gas to the energy matrix of São Paulo State.

The project also includes the development of a GHG emission reduction framework for partial or full substitution of diesel oil by biomethane, a renewable natural gas. The research will include the revision and evaluation processes involved in: i) Biogas production from vinasse , rural and urban wastes, and the different options for its use (biogas, biomethane, hydrogen production, biomethane injection into NG pipelines or as compressed natural gas- CNG); and ii) Biomethane fuelling engines in vehicles (with particular focus on the transportation and agricultural equipment used for sugarcane production in the State of São Paulo).

In short, this project aims to analyse the technical and economic perspectives of biogas production and upgrading, both in rural and urban areas, considering the integration of biomethane and NG. The project will assess the corresponding benefits and potential barriers as well as will propose adequate public policies to achieve those solutions.

2. Methodology

In order to achieve the objectives proposed in the project, was first performed bibliographic review of the basic concepts of biogas, biomethane, biogas sources, biogas and biomethane production, energy conversion options for biogas and biomethane, as well as existing legislations in Brazil and experiences on other countries, mainly the revision on biogas/biomethane policies in European Union.

Was also performed the for biogas potential assessment, by means of appropriate methodologies. The results already obtained for biogas and biomethane potential evaluation from different sources (landfills, sewage stations, animal residues and vinasse from ethanol distillation) in Sao Paulo State are presented in the item Results.

All information and potential evaluated on biogas and biomethane production will be georeferenced using the ArcGIS software, the result of this activity will be maps that showing the points with biogas generation potential in São Paulo State.

The next steps the project, planned for 2017, includes the elaboration of three roadmap, being: a) technologies available to be used for biogas and biomethane production; b) end uses for biogas and biomethane production; c) international and national regulatory aspects related to production and uses of biogas/biomethane.

3. Assessment of theoretical potential of biogas/biomethane production

3.1 Landfills

In the case of biogas from landfills, it is important to understand the current situation of solid residues (Municipal Solid Waste – MSW) in Brazil. The country still has only 58% of MSW disposed in a adequate disposal, with more than 1,500 dumping disposals, more than half in Northeast region (lowest HDI).

The Federal law 12.305/10 introduced the National Policy on Solid Residues (NPSR) which establishes guidelines for the management of solid waste that reflect the non-generation, reduction, reuse, recycling, treatment of solid waste and disposal of environmentally appropriate rejects.

The adequate collection of biogas and its use as energy source – or transformed into biomethane through the upgrade process – surely can contribute to the economic feasibility of the adequate disposal of MSW.

Landfills are considered the most correct way of waste disposal considering environmental aspects.During the anaerobic digestion process of organic matter in municipal solid waste is the formation of two vectors polluters of the environment: manure, liquid pollutant, dark in colour and nauseating odour, and biogas. The landfill must include the soil waterproofing with adequate geotextile to prevent slurry infiltration into the soil. There must be, too, a biogas extraction system and slurry within the landfill.

It is worth noting that biogas extraction process in landfills is incomplete because it allows recovery of 40 to 60% of the biogas produced, due to its collection efficiency.

To evaluate the theoretical potential of biogas/biomethane production, first survey was carried out of the estimated population in 2016 to every municipality in the state of São Paulo. The information was obtained from SEADE, 2016. For quantification of MSW in the municipalities analyzed in this study it was adopted MSW generation per capita in São Paulo equal to 1.1 kg / person / day (PREFEITURA DE SÃO PAULO, 2014). With the MSW generation index and the resident population in the municipalities of São Paulo it was possible to calculate the estimated amount of MSW produced in 2016 for each municipality.

The amount of MSW collected was calculated from the amount of MSW generated and the coverage area presented in the Atlas of Human Development in Brazil (2013), which is a platform for consultation with the Human Development Index of municipalities (PNUD, Ipea, FJP, 2013).

To evaluate biogas generation potential from landfills, the methodologies tused are those suggested by the Intergovernmental Panel on Climate Change (IPCC, 2006) Guidelines for National Greenhouse Gas Inventories.

The potential calculations of methane generation from MSW in this part of the study were made from the total population of each municipality and the average MSW generation per capita of Brazil, in addition to data provided by the IPCC, as described above.

It should be noted that the generation of methane from solid waste disposal there is variation over time as it increases or decreases the disposal of organic matter. Thus, the calculation of methane generation potential refers to the potential generated methane over a year array, excluding methane that may already be emitted from the waste deposited previously. The amount of emitted methane may increase with the increase of waste contained in the landfill with the passage of time and vice versa, as the curve of methane generation has an increasing trend during the period in which the landfill receives waste - each new ton deposited waste, sum up new potential for biogas generation. The peak of the curve occurs in the final year of waste disposal in landfills and from there the curve is governed by the decay constant, related to the degradation of organic matter in time.

For the amount of biomethane produced in each municipality, it was considered that 50% of the biogas produced, after purification, is transformed into biomethane. Importantly, according to the ANP Resolution No. 8, of 30.01.2015 mentioned above, biomethane should have in their composition at least 97% methane (ANP, 2015).

3.2 Sewage stations

The sanitation supply is critical in terms of quality of life, because its absence causes pollution of water resources, bringing harm to the health of the population, particularly the increase in infant mortality.

According to the National Basic Sanitation Survey (IBGE, 2008), of the 5,564 municipalities in Brazil, only 3,069 collect sewage (55.2%), from which, 1,587 receive treatment in wastewater treatment plants.

In São Paulo most municipalities has sewage disposal system in almost every urban area. Many, however, do not yet have a sewage treatment system, which is severe damage to the environment and water sources. In addition to compromising the water quality of rivers, raw sewage dump brings a serious risk of spread of disease.

In Brazil, a wide variety of systems are used for the treatment of sewage. Nevertheless, a large portion of the waste generated is still released directly into water bodies without treatment. For sewage treatment, anaerobic digestion plays an important role, contributing to a significant reduction in pollution potential, and allowing the recovery of energy in the form of biogas (FISHER et al., 1979; LUCAS JR, 1998).

Anaerobic bio digesters are equipment used for digestion of organic material. The predominant technology related to anaerobic systems in Brazil is the UASB (Up-flow Anaerobic Sludge Blanket). It is the most widespread for the treatment of sewage in Brazil. This type of biodigester has a sludge layer that allows liquid to pass and removes the organic nutrients generating the gas phase.To evaluate the theoretical potential of biogas/biomethane production, first survey was carried out of the estimated population in 2016 to every municipality in the state of São Paulo. The information was obtained from SEADE, 2016.

To quantify the sewage produced in the municipalities analysed in this study adopted the average sewage produced per day per person, according to ABNT NBR 7229/93, being equal to 160 l/day = 0.16 m3/day (average sewage produced per year per person = 58.4 m3/year).

With the index of sewage generation and the resident population in the municipalities of the state of São Paulo it was possible to calculate the estimated amount of sewage produced in 2016 for each municipality.

The amount of collected sewage was calculated from the amount of generated sewage and coverage area presented in the Atlas of Human Development in Brazil (2013), which is a platform for consultation with the Human Development Index of municipalities (PNUD, Ipea, FJP, 2013).

To calculate the amount of methane generated in wastewater treatment plants use the methodology presented by CENBIO/IEE/USP (2012).

For the amount of biomethane produced in each municipality, it was considered that 50% of the biogas produced, after purification, is transformed into biomethane.

3.3 Animal residues

The high rate of greenhouse gas emissions in Brazil is due to agricultural activity, since the methane emission by ruminants to deforestation and changes in land use, caused by the expansion of the activity and / or the need of monocultures in which also aims to feed.

The agriculture contributes more than 35% of emissions of greenhouse gases (GHGs) in the country (MCTI, 2013), currently ranking first among the sectors involved (Energy, Industrial processes, Agricultural, Forests and Waste).

Livestock is considered a major cause of environmental damage and among the main impacts we can include: the elimination and / or reduction of native fauna and flora, as a result of areas of deforestation for the cultivation of pasture; and production and GHG emissions.The activity is considered by environmental agencies as "potentially causing environmental degradation," being framed as large pollution potential. The Environmental Law (Law 9.605 / 98 - Environmental Crimes Law), the producer can be held criminally responsible for any damage caused to the environment and the health of humans and animals.

The negative impacts caudate by livestock are correlated with the main production method adopted by Brazil, the extensive system. This is characterized by low investment in training (especially when the acquired land already contains some sort of pasture) and maintenance of pasture (DE ZEN, 2008). But changes are already occurring in the creation process, in which part of the fattening is done by confinement, called intensive livestock.

Animal production intensive systems consist of restricting the physical space where the animals are produced and provide food and water troughs. The purpose of these systems is to increase productivity, or produce more in less physical space and time, reduce the age of slaughter, accelerate return on invested capital, and reduce idleness of refrigerators in the off season (MANSO & FERREIRA, 2007 apud TESTON, 2010).

In this intensive creative process, factors related to the accumulation of waste, generation of liquid wastes with high organic load concentrations can cause direct pollution that location, with consequences in every area of indirect influence, affecting environmental quality, mainly due to the possibility of contamination of water resources (MANSO & FERREIRA, 2007).

Given the reality of the agricultural sector, the treatment of waste from animal creations becomes a necessity due to the high content of organic matter present there and the large amount generated by the activity. If these residues do not have proper treatment, the risks to the environment are significant, causing pollution and eutrophication of water bodies, among others.

One of the solutions to solve the problems of this waste is anaerobic treatment. In rural areas, besides UASB biodigester, it is also possible to be used biodigester model known as covered lagoon, which uses the geometry of the anaerobic treatment lagoons to coverage order to capture the biogas generated.The theoretical potential of the calculation methodology of biogas from animal waste and agro-industrial animal was calculated by Naraisa Moura Esteves Coluna (COLUNA, 2016) in your Master's thesis from entitled "Analysis of potential energy waste from the agroindustrial chain animal protein in the state of Sao Paulo", and adapted to be used in this report.

The size of pig herd was obtained from Livestock Production Municipal - PPM 2014 / IBGE, and the cattle herd in confinement from the First Paulista Census Cattle Confined. Based on these figures it was evaluated methane production from cattle and swine production, using the methodologys of CETESB (2006) and of IPCC (2006).

To evaluate the potential of waste from cutting poultry breeding it must be used the residue called poultry litter as it is this waste that the waste of the chickens are retained.

Some studies have shown that poultry wastes present a higher potential for biogas production when compared to others (mainly from cattle). Therefore, they present a high methane content, what makes this waste more interesting (Hill, 1983; Mahadevaswamy & Venkataraman, 1986).

For the estimation of the amount of biomethane obtained from the biogas purification, the concentration of methane in biogas from cattle and poultry is considered 60% and in swine is 66%. In these estimates the methane losses in the process were not considered, ie the volume of biomethane is exactly the volume of methane present in the biogas.

3.4 Agro-industries

The industrial sector in São Paulo State corresponds to 36% of the Brazilian industrial production; agricultural sector is responsible for 12% of the agricultural income in Brazil and 33.5% of revenues are generated by the service sector (IBGE, 2013).

The agribusiness sector has a significant share in São Paulo State, being the largest producer of oranges, sugarcane and ethanol from sugarcane. The state also produces meat and other agricultural products. Regarding food production, 35.5% of the Brazilian production is concentrated in São Paulo; where sugar production corresponds to 58%, canned fruits and vegetables 48%, dairy products 31% and ground coffee 37%.

In general, the agro-industries process raw materials that generate solid wastes that can be treated anaerobically and produce biogas.

Considering ethanol production in São Paulo, the production increased 64.4% between 2003 and 2012, when more than 11.6 billion litters were produced, representing about 51% of total Brazilian production (Invest São Paulo 2016). According to Invest São Paulo (2016) too, the economy of the sugar and ethanol sector accounts for 44% of the entire agriculture and livestock segment in São Paulo.

Therefore, preliminary estimates will focus sugarcane segment for the estimate of biogas potential production.

In São Paulo, this important segment has a large potential for biogas generation. Consequently, this segment has a huge potential for producing biomethane from the biogas due to large amounts of vinasse produced.

Vinasse is a by-product of ethanol distillation, produced in large amounts. Each litre of ethanol produces around 10-14 litres of vinasse (Poveda, 2014). In the first years of Proalcool, vinasse was not properly discharged, being mainly discharged in rivers, with strong pollution damages (fishes dying and water contamination).

Environmental legislation and adequate enforcement forbidding this practice allowed other uses for vinasse, mainly fertirrigation. Since vinasse contains large amounts of potassium and other minerals, it is a significant environmental and economic option for fertilization and irrigation, replacing fertilizers from fossil origin. Vinasse cannot be disposed in a too high concentration for not to contaminate underground waters ; also, in soils with a high concentration of potassium it is not recommended to be used. In Sao Paulo State, CETESB controls the amount of vinasse disposed in the soils (CETESB, 2006).

More recently, some mills have started to use the process of vinasse biodigestion for energy conversion, but the process is not yet adequately disseminated. Biogas from vinasse presents one of the highest potentials for energy generation, including biomethane production in Sao Paulo State. The high number of mills in the state allows significant scenarios for biogas production. However, conservative behaviour and lack of incentives does not allow the real development of such potential.

In the case of Sao Paulo State, in order to demonstrate the importance of organic waste generated, we can use the production of the 11.6 billion litres of ethanol in 2012 in the state. If we consider an average of 12 litres of vinasse per litre of ethanol, in 2012 we can estimate that it was produced a total of 139 billion litres of vinasse.

The possibility of generate large amounts of biomethane makes it economically viable the injection of the biomethane in gas distribution network when this infrastructure is present in the region.

According to Moreda (2016), the anaerobic digestion of organic waste (vinasse) depends on the conditions in which the process is carried out, as well as several factors such as type of reactor, residence time (for the cases where the system is continuous or batch), temperature, mixing performance, kind of microorganisms, presence of antibiotics or not, etc.

The experiments carried out in different conditions and at different scales allow the determination of optimal conditions of degradation and, consequently, the potential for anaerobic digestion. The values for different categories of waste are obtained in literature. With these values, is possible to estimate the degradation of waste in terms of the reduction of Chemical Oxygen Demand (COD) or Volatile Suspended Solids (VSS).

It is important to notice that the specific amount of biogas produced (per waste unit), as well the total waste generation and the maximum theoretical potential for biogas production can be calculated for each type of waste. However, only a fraction of the total waste generated may be used for the production of biogas. There are always restrictions that inhibit the full use of the waste or are there alternative uses for waste, as discussed in Poveda (2014).

Thus, the available potential for biogas production must be calculated considering these restrictions. In this way, we obtain an estimate of the minimum and maximum amounts of available waste and the corresponding potential range available biogas production. For the development of the potential of biogas/biomethane production in Sao Paulo State, the following scenarios are being considere:

- Baseline – fertirrigation with vinasse (as used in all mills in Sao Paulo State, and controlled by the Environmental Agency, CETESB)

- Vinasse concentration and (anaerobic) biodigestion process

- Vinasse biodigestion and electricity production

- Vinasse incineration and electricity production

- Vinasse biodigestion + concentration + vehicular use (vehicular use in tractors replacing diesel oil or future injection in natural gas pipeline).

4. Preliminary results

Table 1 presents the preliminary results of biogas and biomethane production of theoretical potential in the state of São Paulo.

Table 1. Preliminary results – Biogas and biomethane produced in São Paulo

Biogas producer	Biogas produced (m3/year)	Biomethane produced (m3/year)
Landfill	2,419,431,874	1,209,715,937
Sewage treatment	430,988,422	215,494,211
Vinasse	2,610,409,911	1,501,032,721
Rural residues (animal)	132,753,420	66,376,710
TOTAL - SÃO PAULO	**5,593,583,627**	**2,992,619,579**

Source: Authors 'elaboration

Considering that the natural gas consumption in São Paulo State (2014) was 6,181,819,805 m^3/yr[1], results show that the biomethane production could replace 48 % of NG consumption in São Paulo State.

Due to the biogas flow, it was possible perform the calculations for power (kW) and energy (kWh/year) available. Table 2 shows the power and energy available from biogas obtained from sources analysed in this study.

Table 2. Preliminary results – Potential power and electric energy available in São Paulo

Biogas producer	Potential power (MW)	Electric energy (GWh/yr)
Landfill	495	3,769
Sewage treatment	88	671
Vinasse*	798 (Harvesting season)	4,067
Rural residues (animal)	26	207
TOTAL - SÃO PAULO	**1,407**	**8,714**

* considering 5856 hours of harvest operation

Source: Authors 'elaboration

Considering that the electricity consumption in São Paulo State (2014) was 150,723 GWh/year (SÃO PAULO/SECRETARIA DE ENERGIA, 2015), the electricity produced could be 5.8% of electricity consumption in São Paulo State.

It is noteworthy que During the literature search were found biogas potential values Which differ Considering the substrate. In the next phase of the project is expected to understand the differences between the values calculated by the researchers of this project and values calculated by other researches. During next phases of the project, and based on more detailed information, further results will be available.

[1] According to Secretaria de Energia do Estado de São Paulo. Anuário Estatístico de Energéticos por Município. 2014

5. Conclusion

The INDC (Intended Nationally Determined Contribution) from Brazil presented in last COP 21, in Paris was ratified on September 12, 2016 by the Brazilian Congress. This proposal establishes the following goals to be achieved by Brazil related to carbon emissions:

- By 2030: reduction of 43% compared to 2005.
- Increase the share of biofuels in the Brazilian Energy Matrix up to 18% by 2030.

On another hand, since 2009 there is the São Paulo State Climate Policy, approved on 9 Nov 2009, aiming a 20% reduction on GHG emissions from the state by 2020 compared to 2005. Considering that, in 2005, carbon emissions in Sao Paulo State were 88.8 million (metric) tonnes of CO2, a 20% reduction by 2020 corresponds to 17.7 million tonnes of CO2 (tCO2)

In 2014, the state emissions were 84 million tones of CO_2, being 32.70 million tCO_2 from diesel and 9 million tCO_2 from natural gas (SÃO PAULO/SECRETARIA DE ENERGIA, 2015). If the biomethane produced from vinasse can contribute to reduce 59.7% of diesel in the State[2], this means a reduction of 16 million tCO_2. This reduction is almost the amount to be reduced according the São Paulo State Climate Policy.

The preliminary results presented figures show the important contribution of biogas and biomethane to emissions reduction in Brazil and to reach the goals of Paris Agreement.

This is the main reason for the contribution of Project 27 in RCGI: to contribute to reduce carbon emissions in Brazilian energy matrix, through the replacement of fossil fuels, besides the strategic benefits of increasing the natural gas offer.

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