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Energetic Potential of the Biogas from Urban Solid Waste Generated in the Jacareí Municipal Landfill, Brazil

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Abstract- The use of biogas from solid waste is a way to produce renewable and clean electric energy and presents itself as an alternative to make up the country's energy matrix as well as a solution to the serious problem faced by municipalities that is the accumulation of waste. In this article it was evaluated the potential of the biogas from the landfill of the municipality of Jacarei which has an estimated population of 277,800 inhabitants and a daily waste volume of around 140 ton/day. From the estimated volume of biogas produced in the landfill, about 11.43 million m^3/year at maximum production, the annual electricity generation value was 3.81 GWh. However, based on the scenarios and assumptions adopted, a possible project implementation would not be economically viable. The study reinforces that a minimum amount of waste is needed to enable this alternative as energy production purpose, but encourages other assessments within existing conversion technologies as well as signaling the need for incentives and policies that make such projects viable. The positive result of the study is achieved when the greenhouse gas emissions (GHG) avoided is analyzed, since methane (CH_4) and carbon dioxide (CO_2) are gases that most contributes to the GHG effect.

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Strictly as per the compliance and regulations of:

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I. Introduction

The production of solid waste has become a serious problem for public administrations. The lack of planning and housing policies contributes to the disorderly occupation of cities and to the emergence of inappropriate waste disposal sites and the appearance of dumps.

In Brazil, the National Solid Waste Policy (Federal Law 12305/2010) [1], was processed for more than 20 years in Congress before its approval and use in 2014. In accord to this policy, solid waste must be treated in landfills.

Several available technologies around the world permit recovering energy from solid waste. Brazil has great potential for using solid waste as an energy source, even on a small scale would support in the long term a strategy of expanding the country's supply of electricity or biofuel.

There is a worl concern with reducing the atmospheric concentration of greenhouse gas (GHG) that encourages the public sector to establish laws and investment in renewable energy.

The objective of the present study is to quantify the potential of the methane gas in generating electricity. The study will consider the biogas from the solid waste disposed in landfill located in the muncipality of Jacareí-SP, analying the economic feasibility of implementing a biogas plant considering the revenues obtained from the commercialization of the generated energy. As a secondary objective, the avoided GHG emissions will be calculated from possible scenarios for the disposal of solid waste.

a) *Solid waste situation in Brazil*

Currently, Brazil has a Federal Law 12305/2010 [1] that establishes guidelines for the National Solid Waste Policy (PNRS). Until the establishment of the PNRS, other laws dealt with this matter. However the PNRS came to regulate the final destination of the solid waste, which including urban waste, acting as a regulatory framework that brings together instruments and guidelines that the agents involved must follow.

In general, waste is considered any material that, after its use, has lost its primary functionality. According to the Brazilian Standard NBR 10004 [2], it is also considered as municipal solid waste (MSW) the sludge residues from the sewage treatment plant (ETE), those generated in equipment and installations to control pollution and liquids, which due to some particularity, they cannot be released into public sewers or water bodies. According to Federal Law 12305/2010 art. 13[1] the solid waste can be origined for:

- Urban solid waste, those originating from domestic activities in urban homes and those originating from sweeping, street and public roads cleaning and other urban cleaning services;
- Commercial establishments and service providers activities;
- Public basic sanitation services activities;
- Industrial generated by transformation processes and activities;
- Health services waste, those defined in accordance to regulations or norms established by supervisory bodies;
- Civil construction waste, those generated in constructions, renovations, repairs and demolitions

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of civil works, including those resulting from excavation for land preparation and civil works;

- Agricultural, arising from the productive activity of the primary sector.
- Transport services waste, those originating from ports, airports, customs, road and rail terminals and border crossings; or
- Mining waste, those generated in the activity of research, extraction or mineral processing

In this article, only urban solid waste will be treated.

According to ABRELPE [3], the total ammount of waste generated in Brazil in 2019 was 79 million ton/year. About 92.0% of this total was collected. The Fig. 1 compares the percentage of waste disposal that had an adequate final destination (landfills) and inadequate final destination (disposed in controlled landfills and dumps), concluding that about 5 million ton/year were still not collected.

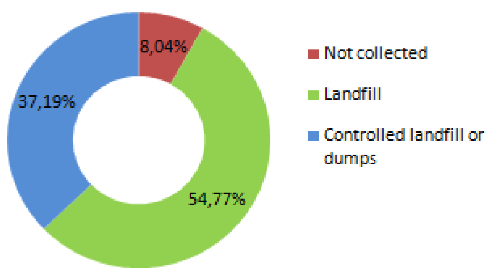

Fig. 1: Final destination of MSW collected in Brazil in 2019 (ton/year) [3]

The initial deadline of the PNRS for the municipalities eradicating irregular landfills and effectively implemented the solid waste management expired in 2014. In 2020 a new deal was established: all capitals and metropolitan regions must eliminate dumps until August 2021; cities with more than 100,000 inhabitants have until August 2022 and for those with less than 100,000 inhabitants the deadline is August 2024. Recycling collection and material separation are significant components of MSW minimization. However is important to highlight that only 73.10% of the municipalities carry out selective waste collection as shown in Fig. 2.

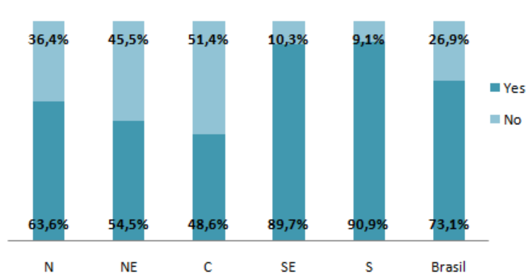

Fig. 2: Selective waste collection in municipalities in 2019 – Regions and Brazil [3]

b) The problem of urban solid waste and its energy use

The decomposition of materials could generate toxic gases that contaminate the soil, water, air and population [3], so the inadequate destination of residues is responsible for serious environmental impacts.

Disposal in landfills remains the main form of MSW disposal method. However, it is known that landfills are major contributors to the emission of GHG. An alternative to minimize its effect is the energy use of MSW for energy generation [4]. Solid waste gases are composed of 50% to 60% methane (CH_4), 40% to 50% carbon dioxide (CO_2) and smaller proportions of other gases such as ammonia (NH_3), hydrogen (N_2) and oxygen (O_2) [5]. These gases are generated during the decomposition of organic matter that occurs by two processes: aerobic decomposition, from the final disposal of waste in the landfill, and anaerobic decomposition, due to the reduction of O_2. CH_4 and CO_2 come from anaerobic decomposition [6], both are responsible for GHG emissions. CH_4 is the second most important GHG emissions, after CO_2 and its global warming potential is 21 times greater than CO_2 [7].

Therefore it is fudamental analyzing the feasibility of implementing plants for the energy use of MSW as an environmental alternative and as a business opportunity. Incineration and biological processing of MSW are examples of energy use that can drastically reduce the area needed for landfills [6]. Recycling is also considered an efficient form of energy use, as it allows the recovery of raw materials used in the production process, where energy consumption is normally higher. The energy use from biogas, commonly known as landfill gas (LFG), can be used in two ways: as a substitute or complement to natural gas, in this case a purification process is need [8], or as electricity generation that will be the object of this study [6].

c) Electricity generation from biogas

The energy use of biogas for electricity generation requires the installation of equipment to operate and monitor the system as shown in Fig. 3.

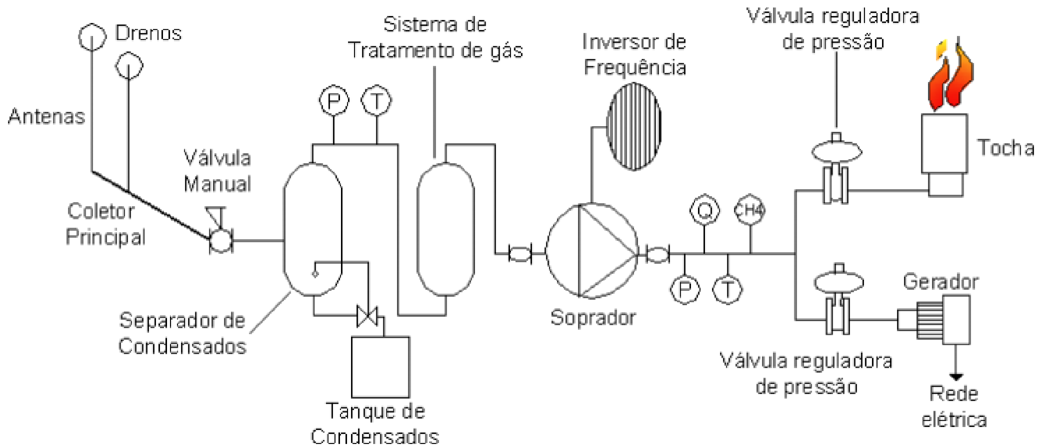

Fig. 3: Simplified diagram of biogas capture and treatment process [9]

Landfilling as a method of MSW disposal management does not contribute to a significant reduction in the volume of accumulated waste. Other alternatives, as incineration for example, are more efficient for reduce the amount of wastes that go to landfills. The continuous disposal of waste will definitely end up depleting the landfill's volume capacity.

Investments into plant of producting electricity from energy recovery of biogas should be considered important strategies for energy policies: as renewable energy sources and as an added benefit of avoid GHG emissions. The government should make more efforts to promote improvements, incentive programs, laws and policies. The Federal Law 10438/2002 [10], for example, has the objective of expanding the use of renewable energy. Through the Federal Law 9427/1996 [11], public or private companies that operate the landfill can organize itself as a self-producer or independent producer.

Two normative could also improve the economic viability of producing electricity from MSW: revenues from the sale of electricity or in the compensation scheme, with permit a reduction in the value of the electricity bill, as provided the Normative Resolution 687/2015 [12]; free fee of use of electrical transmission and distribution systems, as characterized in the Normative Resolution 271/2007 [13].

II. Materials and Methods

The option adopted to select the municipality of Jacarei to be addressed in this study was based on the document "Study on the potential of energy generation from waste (garbage, sewage)", in order to increase the use of biogas as an alternative of renewable energy source [14]. These criteria take into account the population data of the city (population greater than 200,000 inhabitants), as well as the minimum amount of waste necessary to enable projects to recover biogas from landfills for the purposes of energy generation and biogas production. It is also considered a potential production for a period of at least fifteen years.

As this study intend to evalution the potential for producing biogas from urban solid waste for generate eletricity purpose, the data needed are: waste demand, considering population growth, year of start and end of waste disposal, gravimetric composition of the waste, climate, temperature and rainfall in the city, among others. These informations were based on the Municipal Plan for Integrated Solid Waste Management – PMGIRS referring to the municipality of Jacarei [15].

a) Characterization of the municipality of Jacareí

The municipality of Jacareí is located in the Paraíba Valley, between Rio-São Paulo, 80 km from the capital of São Paulo and 350 km from Rio de Janeiro. The area is 464 km^2. The latitude and longitude coordinates are: - 23° 18' 10' south and - 45° 17' 31" west. Its altitude varies between 567 to 730 meters. The time zone is UTC-3. The population according to 2010 census was 211,214 thousand inhabitants. The city's climate is tropical from altitude to subtropical, with dry winter. The temperature presents an annual average of 21°C. July is the coldest month, temperature around 13°C and Februar is the hottest, temperature around 25°C. The annual rainfall index is around 1.475mm.The geographic location is shown in Fig. 4.

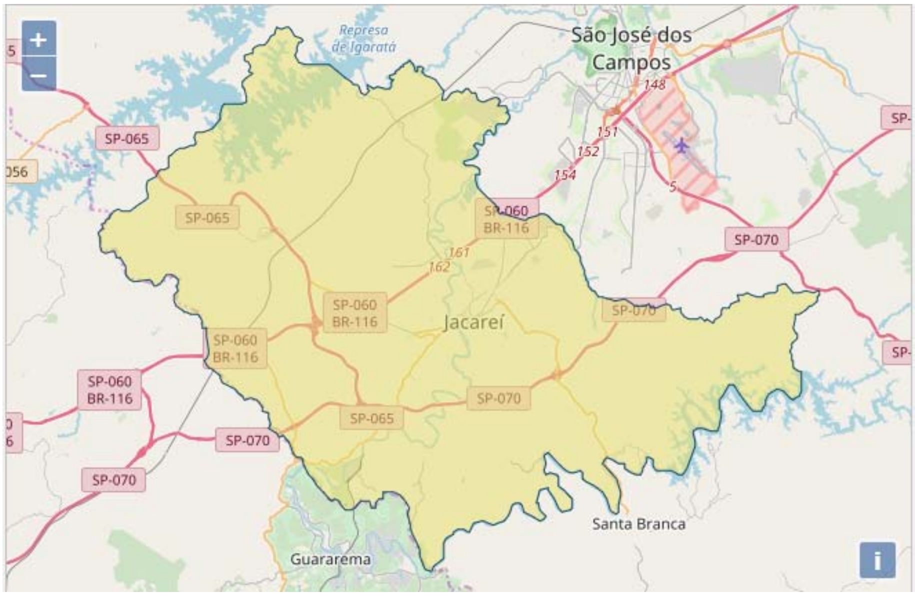

Fig. 4: Geographic location of Jacareí [15].

Two order municipalities, São Silvestre de Jacarei and Parque Meia Lua, make part of Jacarei. The economy is based on three sectors of activities: agriculture (0.39%), industry, (51.74%), and services (47.87%).

b) Landfill and useful life

The landfill has an area of 792,550 m² located at a geographic coordinates N = 7,422,300 and E = 406,100. The landfill operation started in 2018 and it was projected to receive the household waste until 2040 but its useful life can be greatly increased with the recycling of waste. The MSW volume should be gradually reduced with the implementation of the environmental education plan, sorting unit, selective collection and the operation of the biodigestion plant.

c) Population data

The demand for urban cleaning services and MSW management services is calculated as a function of the population growth projection. The PMGIRS of Jacarei presents this projection with a 25-year horizon: it starts in 2015, the year of the forecast for the beginning of the actions foreseen in the PMGIRS and runs until 2040. The population growth of Jacarei accelerated with industrialization. The growing development of industries has led to boosted migration to the municipality, mainly in urban areas. Analyzing the data presented in the PMGIRS of Jacarei, it is possible to see that the urban population represents 98.62% while the rural population is 1.38%. Table 1 shows the estimated projection from 2020 to 2040 (expected year of landfill useful life) according to the PMGIRS of Jacareí.

Table 1: Population projection of the Jacarei municipality [15].

Year	Estimated population	Year	Estimated population
2018	228,358	2030	256,801
2019	230,600	2031	259,329
2020	232,864	2032	261,883
2021	235,151	2033	264,463
2022	237,461	2034	267,068
2023	239,794	2035	269,700
2024	242,151	2036	272,359
2025	244,532	2037	275,044
2026	246,937	2038	277,756
2027	249,366	2039	280,496
2028	251,819	2040	283,263
2029	254,297		

The population projected in the PMGIRS was made from the analysis of census data and using the geometric method. According to the PMGIRS, this method is most suitable due to the rapid growth of the municipality and its size, with a growth rate of 1.01% per year for the total population and 0.99 % per year for rural population. The geometric method can be used, in most cases, when the municipality is in a phase of accelerated growth, as seen in Jacareí and generally follows the exponential curve. The formula that calculates the projection is given by equations (1) and (2):

$$P = P_0 * q \qquad (1)$$

$$q = (P / P_0)^{\wedge (1/t-t_0)} \qquad (2)$$

Where:

q - geometric growth rate;

P_0 - initial population based on the last known census;

t_0 - year of the last census;

P - final population or that of the desired year;

t - desired year (projection horizon).

d) Per capita generation of urban solid waste in Jacarei muncipality

The per capita generation of solid waste is the daily amount of waste generated by each inhabitant [16]. Based on a survey carried out with the population, the PMGIRS elaborated the projection of demand for the urban solid waste and established short, medium and long-term goals for the amount of waste generated per capita, which are shown in Fig. 5.

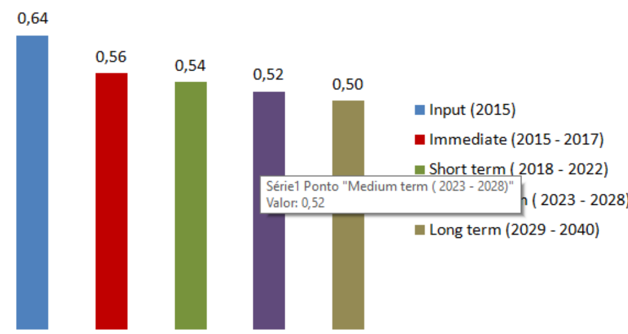

Fig. 5: Targets per capita for the urban solid waste generation (kg/inhabitant day) [15]

The population projection of Jacarei muncipality and the quantities of urban solid waste generated will permit the subsequent calculation of the methane production. The Fig. 6 was elaborated from the data informed in the PMGIRS.

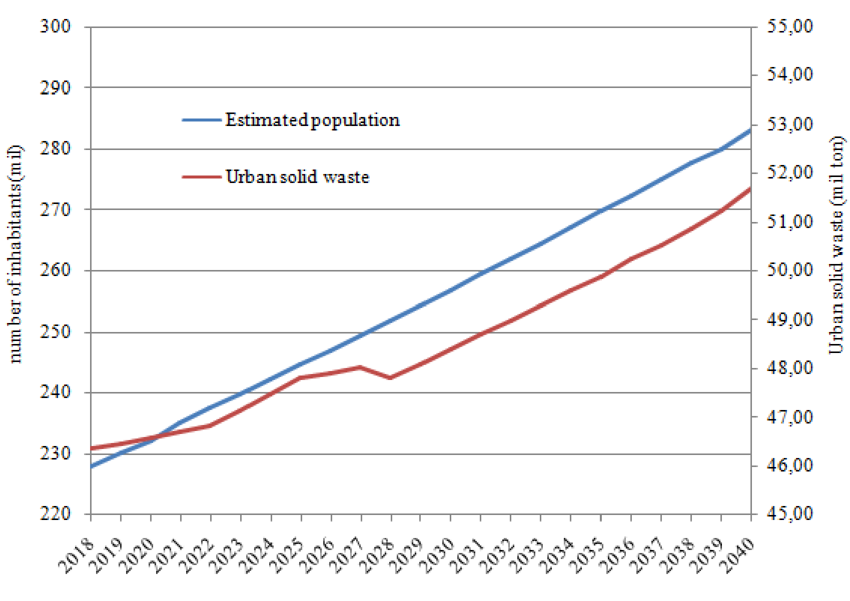

Fig. 6: Population projection and waste generation

e) Urban solid waste characterization

The composition of solid waste is influenced by several factors: number of inhabitants, purchasing power, educational level, habits and people's custom, climate conditions, changes in the country's economic policy [6]. According to the PMGIRS of Jacarei, which based on data from the Department of the Environment of the Municipality of Jacareí, the characterization of urban solid waste in the municipality is as presented in Table 2.

Table 2: Urban solid waste solid characterization of the Jacarei municipality

Composition	Weight (ton/month)	%
Recyclable	89.51	2.17%
Household waste	4,037.32	97.83%
organic	3,216.08	77.93%
waste	821.24	19.90%
Total	4,126.83	100.00%

f) Waste Reduction Model (WARM)

The Waste Reduction Model (WARM) was created by the United States Environmental Protection Agency (EPA) [17] and allows reporting of GHG reductions from different waste management practices such as source reduction, recycling, anaerobic digestion, combustion, composting and landfill. In this work, version 12 of the tool available on the EPA website was used. The metric for emissions results is relative to the measurement of one ton of CO_2 equivalent ($MTCO_{2eq}$).

Based on the waste characterization presented in Table 2 it was possible to develop different scenarios to different solid waste management practises.

The mass of waste used will be the estimated production in 2040 according to population projection and waste generation presented in Fig. 6. As 2.17% of the waste is recycled, the baseline scenario (Fig. 7) will consider this part of recyclables and the landfill of organic waste and of the tailings. It will be analyzed 3 scenarios according to Fig. 8; Fig. 9 and Fig. 10.

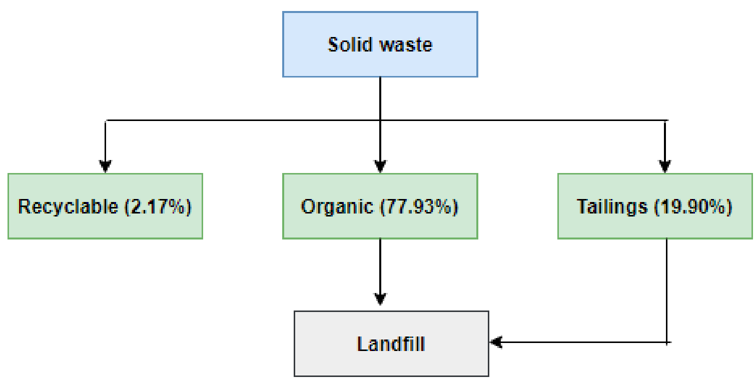

Fig. 7: Schematic summary of scenario baseline

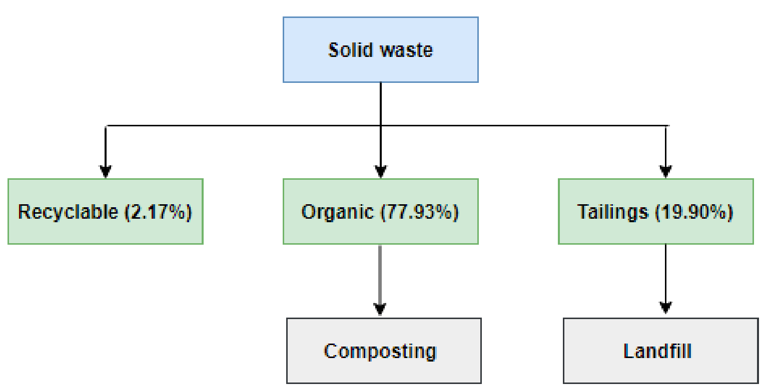

Fig. 8: Schematic summary of scenario 1

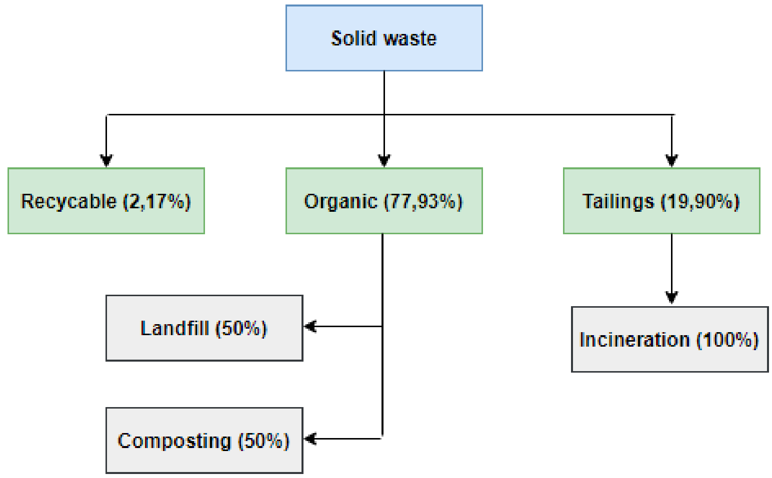

Fig. 9: Schematic summary of scenario 2.

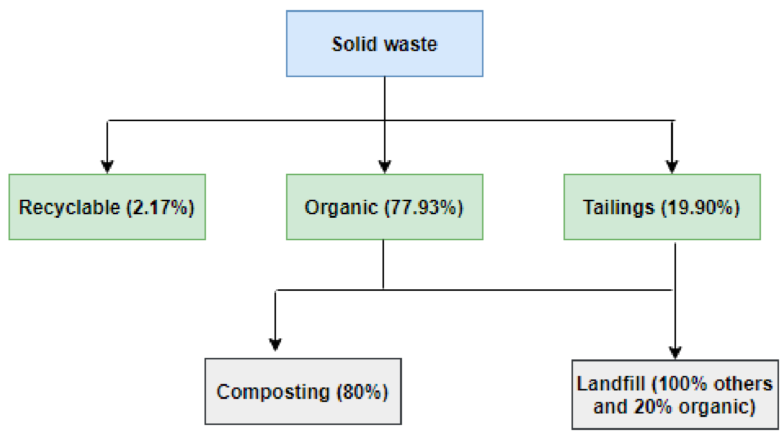

Fig. 10: Schematic summary of scenario 3

g) Land GEM

There are theoretical and experimental formulations to determine the potential of gas generation from landfill. The experimental ones consider the real measurements and therefore their determination is more difficult. In this work, the theoretical formulation will be used. In Brazil there is no developed methodology that takes into account local peculiarities, such as waste composition, climate and landfill operation. The model adopted for this study, the software Land GEM (Landfill Gas Emissions Model), is a program developed by EPA [18]. In this model the standard inventory and parameters were developed from empirical data from US MSW landfills. Land GEM accounts the amount and variations in landfill gas generation, calculating the emission of CH_4 and the emission of 49 other components, including CO_2. The Land GEM equation in version 3.02 considers the generation of methane with an increment of 0.1 each year, producing a small reduction in the estimated emissions compared to previous versions [19].

h) Calculation of the CH_4 emissions

The Land GEM model uses equation (3) to calculate the estimated annual emissions for the specified period.

$$Q_{CH4} = \sum_{i=1}^{n} \sum_{j=0,1}^{1} k.L_0 \left(\frac{M_t}{10}\right).e^{-k.t_{i,j}}$$

Where:

Q_{CH4} - annual methane generation in the year of the calculation (m^3 /year);

i =1 - year time increment;

n - corresponds to the year of the calculation (initial year of opening of the landfill);

j = 0.1 - year time increment;

k - methane generation rate (year-1);

L_0 - methane generation (m^3/ton.);

Mt - mass of waste received in the year in each section (ton.);

$t_{i,j}$ - corresponds to the year, in each section, of receipt of the mass of waste (time with decimal precision).

The parameters L_0 and k are the most important, as they reflect variations according to location, climate and type of waste. Theoretically, the k factor varies from 0.003 to 0.21 ($year^{-1}$). According to IPCC [20], the most rapid rates (k = 0.2) are associated with high humidity site conditions and rapidly degradable waste such as food waste. The slower rates of decomposition (k = 0.002) are associated with dry site conditions and slowly degradable residues such as wood or paper. The Land GEM model suggests a k value of 0.05 as a default value. On the other hand, the L_0 factor is proportional to the percentage of organic materials present in the waste, and it can range from 0 (lack of degradable material) to 300 m³/ton[21]. The default used by Land GEM is a Lo value of 170. Table 3 shows the values recommended by the EPA, the World Bank and the values adopted by the Land GEM model for k and L_0.

Table 3: K and L_0 values

Parameters	EPA	World Bank	LandGEM
k ($year^{-1}$)	0.04	0.06	0.05
L_0 ($m^3CH_4 .t_{MSW}^{-1}$)	100	170	170

In the model adopted by the Land GEM, the default CH_4 and CO_2 content of LFG is 50% for both.

i) Calculation of power and energy

Once the volume of CH_4 was determined through Land GEM it is possible to estimate the power and energy. According to [22], the most used technology for recovering energy from biogas is the internal combustion engines (MCI) due to its economic feasibility. The computer program developed by [23] uses the equations (6) and (7) to estimate the power and energy. The parameters used by this program are in Table 4.

$$P = (Q_{CH4} * PCI_{CH4} / 31{,}536{,}000) * \eta * Er * c \qquad (6)$$

Where:

P - available power per year (MW)

Q_{CH4} - annual methane flow (m³/year)

PCI_{CH4} - calorific value of methane (J/m³)

31,536,000 - Seconds in a year (s/year)

η - energy conversion efficiency according to the chosen technology (%)

Er - landfill gas recovery efficiency (%)

$c = 10^{-3}$

$$E = P * 8760 \qquad (7)$$

Where:

E - energy available per year (MWh)

8760 - hours in a year (h/year)

Table 4: Parameters for calculating the energy use of biogas

Parameters	Value
CH_4 percent by volume of biogas (%)	50
CH_4 recovery index (%)	75
Engine efficiency	0,2

Santos et al. [24] study determines as optimal power, for the dimensioning of a generator set at full load, the value of 45% of the maximum potential.

j) Feasibility Analysis

The economic viability analysis of installing a LFG plant from the landfill in the municipality of Jacareí will be carried out from the net present value (NPV). According to [25], NPV consists on determining the present value of a future values cash flow, discounted at an internal rate of return (IRR). If the present value is positive, the project is attractive and the higher is the positive value, the more attractive is the project.

$$NPV = \frac{FC_0 + FC_1/(1+j)^1 + ... + FC_t}{(1+j)^t}$$

Where:

FC = cash flow of the n^{th} year, in U$;

j = discount rate (%);

t = project lifetime, in years

For the study a period of 20 years was considered, which corresponds to the lifetime of the installation. During this period it will be possible to observe the attractiveness of the project. An IRR of 8% per year was chosen to discount the annual cash flow and calculate the NPV.

The estimed costs for implementation, operation and maintenance (O&M) based on [26] and the reference values in dollar are shown in the Table 5.

Table 5: Installation and O&M costs [26].

Component	Un.	Value (U$)
Preliminary studies	un	12.500,00
Design	un	10.000,00
LFG collection and flare system	un	1.143.000,00
Purchase and installation of equipment	kW	2.400,00
O&M (collection) annual	un	191.000,00
O&M (installation) annual	kW	160,00

It will be considered a financing of 75% of the value of the investment, with an interest of 2.50% per year, depreciated by the PRICE amortization system in 10 years. The interest rate consider as reference is those practiced by the National Development Bank (BNDES) in credit operations for infrastructure projects of expansion and modernization of energy generation from renewable sources [27].

The sale of energy generated by the treatment plant will be considered as monthly revenue. The kWh cost is U$ 0.11. Its reference is the average cost of R$ 0.58/kWh in 2020 taken from [28] and converted to the average quotation of the dollar in reais (R$ 5.15) of the same year in according to BACEN [29].

III. Results and Discussion

a) WARM Results

The results of the WARM for different model scenarios are shown in Table 6 e 7. It is possible to observe that scenario 2 presented better results in terms of GHG emissions, showing a reduction in emissions of 102,494.35 of MTCeq and 375,812.60 of $MTCO_{2eq}$. In addition, this scenario had a greater increase in energy savings of 826,748.03 million BTU, which is equivalent to 142,297 barrels of oil or 6,613,984 gallons of gasoline.

Scenario 1 was presented an intermediate results, wtih a saving in GHG and energy emissions. Analyzing GHG emissions, there was a reduction of 97,394.35 MTC_{eq} and 357,114.46 $MTCO_{2eq}$, therefore, less significant than in scenario 2. However, there was an energy increase of 147,740.73 million BTU.

Scenario 3 was less satisfactory. Comparating this scenario with the baseline, there was a reduction in GHG emissions, but the emissions were still higher than scenarios 1 and 2. Furthermore, an increase in energy use of 118,192.59 million BTU was observed, equivalent to 20,340 barrels of oil or 946,541 gallons of gasoline.

Table 6: WARM results – Total energy use

	Scenario 1	Scenario 2	Scenario 3
Total energy use – MSW generation and management (million BTU)			
Baseline	-292.995,89	-292.995,89	-292.995,89
Alternative Management	-145.255,15	-1.119.743,92	-174.803,30
Incremental energy use	147.740,73	-826.748,03	118.192,59

Table 7: WARM results – Total GHG emission

	Scenario 1	Scenario 2	Scenario 3
Total GHG emission - MSW generation and management ($MTCO_{2eq}$)			
Baseline	331.426,25	331.426,25	331.426,25
Alternative Management	-25.688,21	-44.386,35	45.734,68
Incremental GHG emission	-357.114,46	-375.812,60	-285.691,57
Total GHG emission - MSW generation and management (MTC_{eq})			
Baseline	90.388,98	90.388,98	90.388,98
Alternative Management	-7.005,88	-12.105,37	12.473,09
Incremental GHG emission	-97.394,85	-102.494,35	-77.915,88

b) Land GEM Results

The Land GEM model project the curve of CH_4, CO_2 and NMOC emissions and the biogás production (Fig. 11). It is worth noting that as the model considers the same proportions of CH_4 and CO_2 in the composition of the biogas, the curves of these emissions coincide. The total gas emissions increase noticeably in the period from 2018 to 2040 (from the open landfill to the closure landfill). At the end of landfills useful life (2040) the total of biogas emissions reaches 11.11 million m^3/year, with 5.55 million m^3/year corresponding to CH_4 emissions. When the waste disposal operations in the Jacarei landfill end, it is interesting to note that gas emissions do not cease immediately, but they start to present a sharp decline. Residual biogas emissions take many years to completely stop. It is known that these gases can cause damage to the environment, as well as to human health. Therefore it is necessary to monitor the landfill area even after its closure, avoiding possible accidents in the area.

The Land GEM model identify the peak production of CH_4 and biogas generation as a year after the end of waste disposal in the landfill (2041), with a value of 5.71 million m^3/year to CH_4 emissions and 11.43 million m^3/year to biogas production. The maximum power generated was calculated from this volume of biogas with a value of 966 kW (Fig. 12). The optimal power was found using 45% of the maximum power thereby obtaining the energy (Table 8).

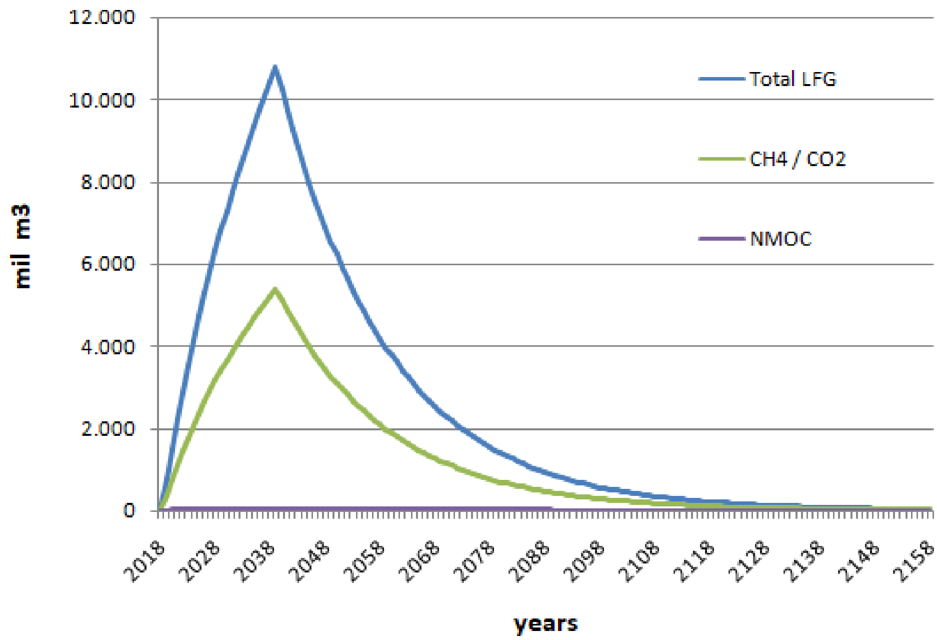

Fig. 11: Total gas emissions by total biogas (LFG)

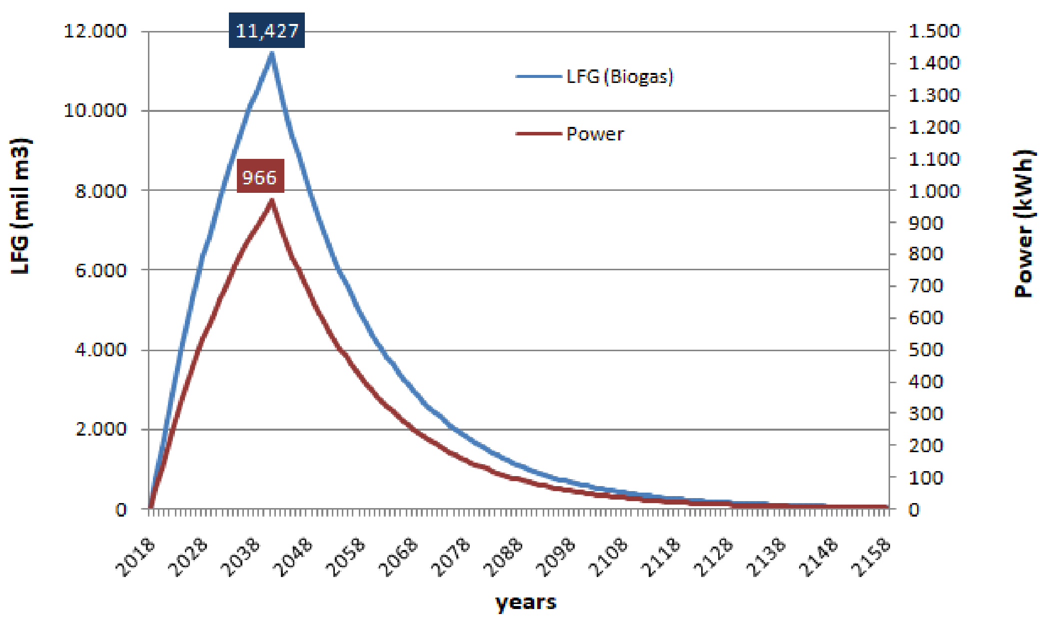

Fig. 12: Biogas evolution and Power

Table 8: Optimum power and energy

Power (kW/year)	Energy (kWh/year)
434,51	3,806,337.14

Table 9: Economic analysis of the biogas energy use

Investiment (U$)	O&M (U$/year)	Revenues (U$/year)	NPV
2,208,332.09	260,522.14	427,844.10	-139,886.28

c) Economic viability

Based on the implementation costs, O&M costs and revenues values, the cash flow and NPV for the biogas plant project were calculated. These values are presented in Table 9.

The energetic use of biogas from MSW failed to present satisfactory values. The revenues from the sale of energy generated over the lifetime of the project do not exeeced the capital investments and operational costs. It is revealed by a negative NPV values.

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Thus, the result confirm one of the major challenges facing in this project is required a minimum volume of MSW for LFG energy use. The investiments required do not make economic sense at small volumes of MSW as already concluded by some authors. The Tolmasquim's estimate [30], for example, it would be around 300 t RSU/day. This is due to the low volume of CH_4 present in the biogas, generally assumed to be a percentage of 50.

IV. Conclusion

The study contributed to reinforce the need to assess and determine the risks of implantating biogas plant projects for energy use. It is strongly recommended that the decision be based on technical and economic feasibility studies. In addition to the balance between income and expenses, future studies indicate the need to use different models to determine the biogas production which should take into account the waste composition and characteristics, climate and other local characteristics.

In most municipalities the volume of MSW are relatively small, thus, alternatives such as involving partnerships between them is need in order to ensure a reasonable volume of waste that become energy use viable. Finance policies and incentives for researching and developing new technologies of low costs would be welcome and would contribute to enhance economically the projects' viability.

The benefit of emissions avoided wiht the energy recovering was not evaluated in this study, disregarding economically the probable revenues from the sale of carbon credits.

The composting and incineration are practices of waste management that as observed in scenario 2 can contribute to reducing GHG emissions and energy savings. It is worth highlighting the use of renewable source instead of fossil resource generate positive impacts to the environment. Other positive aspect is the impact that this kind of project on job creation for the local population. Thus, the environmental and social aspect of energy production from landfill biogas represents the positive part that can make its implementation feasible.

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