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ENERGY POTENTIAL GENERATED BY URBAN SOLID WASTES IN LAGES-SC: EVALUATION OF ITS COST-BENEFITS

[1]Denis Moreira Pereira, [2]Felipe Américo Camargo, [2]Graciela Alessandra Dela Rocca, [3]StéfanoFrizzoStefenon, [2]Nathielle Waldrigues Branco and [2]Fernanda Cristina Silva Ferreira

[1] Student of Electrical Engineering at the University of Planalto Catarinense
[2] Professor at the University of Planalto Catarinense
[3] Coordinator of the Electrical Engineering at the University of Planalto Catarinense

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ABSTRACT

The objective of this work is to analyze the challenges involved in the generation of energy using garbage (urban solid wastes) as the main input, and understand the processes in this type of energy generation in order to estimate the energy potential of the city of Lages. Our purpose is to explain how it works and highlight its benefits to the modern society, especially in view of the growing need of sustainable technologies that lead to human development. Other aspects such as its economic, technical, environmental and social importance are also discussed in this paper to raise awareness and ensure a more promising future for our planet.

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INTRODUCTION

The future of our country and our planet is full of challenges, especially when we think of development in a sustainable manner (Garcia *et al*., 2016). Energy is a vital input for development and the means of sustainable energy generation are extensively studied in order to find cleaner and more efficient alternatives (Barp *et al*., 2016). Today there is not space for not being aware of the importance of the sustainable use of natural resources.Brazil ranks among the top 10 countries with the largest renewable energy matrices, and one of the nations that invest the most in the generation of clean energy. This forefront position encourages the development of new alternatives for renewable energy generation; this data is shown in table 1, where the abbreviation TEP stands for Ton of Equivalent Petroleum.We live in a developing country, and that means that for the near future there will be an increase in energy demand. In a few years, with the recovery in the Brazilian economy, the investments in infrastructure, social mobility, and facilitated access to services and products, as a natural consequence of the improvement of the quality of life of the population, will result in an increase in the average per capita consumption of energy (EPE, 2014, p.8).In order to develop economically and socially, the society needs to come up with more efficient, cost effective energy generation processes, with reduced environmental impacts (Folster *et al*., 2016). That reality is leading to the usage of other types of fuels that weren't so widespread, and it has also led to a decentralization of energy generation plants, with more autonomy both in the generation and in the consumption of electric power (Agostinho *et al*., 2017). However, in order to understand this modality of energy generation and its several usages it is necessary to have a comprehensive knowledge about its origin, advantages and disadvantages, benefits and downsides of its usage. This work aims at identifying the ways and variables of the process of obtaining electric power through Landfills, in order to understand and quantify the potential of this alternative in the city of Lages (SC). To accomplish this goal, we will explain in detail the benefits of recycling solid waste to reduce electricity consumption while highlighting the social and environmental impacts of this process and its importance for a more sustainable development. In Lages we have, according to the municipal Environment Department (2016), approximately 500 solid waste pickers (registered), one solid waste pickers cooperative which is subsidized by the City Hall and several informal groups on the activity. One example is the group Renascer da Cidadania, located in the neighborhood of Santa Mônica.

MATERIALS AND MEHTODS

The methodology utilized in this work is the descriptive-comparative, with a case study, along with empirical and bibliographic data. The case study will be carried out specifically addressing the garbage generated in Lages and its potential to generate electric power through the usage of solid wastes that are currently being dumped in the local landfill. A special emphasis will also be given to the importance of recycling in the process of energy recovery.

Table 1. Ranking Renewable Energyat the DES (2014)

Countries	10^6tep	%
1 China	343	18,1
2 India	209	11
3 United States	152	8
4 Brazil	122	6,4
5 Nigeria	109	5,8
6 Indonesia	78	4,1
7 Canada	50	2,6
8 Ethiopia	46	2,4
9 Germany	35	1,9
10 Pakistan	35	1,8

(Source: MME, 2015)

Methodological procedures: Initially we conducted a bibliographic research for obtaining a broader knowledge of the process, reinforcing the importance ofthe correct management of urban solid waste and its use as a source of energy, for which we obtained references in data and formulas used for the calculation methods.The second phase will be the acquisition of the necessary data for the electric power generation calculations when utilizing urban solid waste in the city of Lages. The amount of waste disposed in the landfill every month, number of urban residents, gravimetric analysis of local solid waste, layout of the disposal area in the landfill, calorific value of the garbage, and amount of recycled material data were collected to make the calculations and later quantification of the results.For the measurement of the biogas generation potential, we are going to use the methodology from the Intergovernamental Panel of Climate Change (IPCC, 1996) as shown in equation (1) with data obtained from the PML (2017) and IBGE (2010).

$$L_0 = MCF \times DOC \times DOC_F \times F \times \frac{16}{12} \quad (1)$$

L_0: waste methane generation potential (m^3biogás/kg_{rsd})
MCF: methane correction factor (%)
DOC: Fraction of Degradable Carbon (kg_c/kg_{rsd})
DOC_F: fraction of dissolved organic carbon (kg_c/kg_{rsd})
F: fraction of methane in the biogas
16/12: conversion from carbon (C) to methane (CH_4)
RSD: Householdsolidwaste

$$DOC = 0{,}4 \times A + 0{,}16 \times (B + C) + 0{,}30 \times D \quad (2)$$

A: percentage of cardboards and fabrics =11,8%
B+C: Foods and other organic waste =51 %
D: woodwastes = 1%

$$DOC_F = 0{,}014 \times T + 0{,}28 \quad (3)$$

T: Temperature (°C) in the anaerobic zone of the residues, estimated at 35°C
F= 50% of methane in the biogas
MCF= 1 (well managed landfill).

Replacing the values found in the equations 3 and 4 in equation 1 we obtained the value of L_0 ($kgCH_4/kgRSD$), taking into account the density of the methane in the Standard conditions for temperature and pressure (STP) of 0,7168 kg/m^3, the value is L_0 (m^3CH_4/t RSD).

For the measurement of the methane flow in m^3CH_4/year, we used the following formula:

$$LFG = k \times Rx \times L_0 \times e^{-k(x-t)} \quad (4)$$

$$k = \frac{ln2}{t^{1}/_{2}} \quad (5)$$

Rx: yearly waste flow (t/year)
X: current year
T: year of disposal in the landfill
t: average time for 50% of decomposition = 9 years
k: Decay constant (1/year) = 0,077

From the data obtained from the estimation of the biogas energy generated in the landfill, we are able to measure the potential for the generation of electric power, by using the following equations (Drummond, 2014):

$$Px = \frac{Qx \times PCI}{31536000} \times ec\left(\frac{K}{1000}\right) \quad (6)$$

Px: available power - year (MW)
Qx: captured methane flow (m^3CH_4/ano)
ec: suggested value for the collection of gases (75%)
PCI: methane calorific value (J/ m^3CH_4)
K: dimensionless constant (1000)

$$E = Px \times \left(\frac{1}{365 \times 24}\right) \quad (7)$$

E: available energy (kWh)
Px: available power/ year (MW)
365: days/year
24: hours/day

Estimation Methodology of the energy potential from the incineration of wastes. With regards to incineration technologies it is necessary to establish the inferior calorific value (ICV) of at least 2.000 kcal/kg (Martin, 2008 as cited in EPE, 2014, p. 38), uses part of the recyclables (with higher calorific value, such as paper and plastic) along with the organic fraction of the garbage for the generation of electric power. Materials such as glass and metals would be removed integrally and, then it was measured the percentage of paper and plastic necessary for the ICV of these mixed with the total of the organic fraction result in2.000 kcal/kg.

(Source: Westmoreland, 2014).

Figure 1 - Waste Incineration Plant in Bremen - Germany

(Source: Westmoreland, 2014).

Figure 2. Incineration plant in Osaka, Japan

Using the formula for the measurement of the ICV created by Themelis (2003) bellow, adapted (EPE, 2014) and not considering glasses and metals.

$$PCI = \{18500[(\%FO \times (1 - \%H\_2O) + \%P + \%Pl) - 2636 \times (\%H\_2O) \times (\%FO) - 628 \times (\%V) - 544 \times (\%M)]\}/4.18 \qquad (8)$$

Where:

%FO = organic fraction participation
$\%H_2O$ = moisture content
%P = paper participation
%Pl = plastic participation
%V = glass participation
%M = metal participation

Part of the weight of the combustible (organic) fraction (putrescible, leaves and wood) should be deducted the percentage of water. The percentage weight of water of these organic materials corresponds to the variable H_2O. In the absence of specific data, the typical value of 60% is used to estimate the water content in these solid urban wastes. In the incineration process the energy contained in the wastes is released, along with the energy released in the burning of auxiliary fuels and the energy present in the pre-heated air injected in the furnace. The potential of the conversion from wastes to energy (MJ/kg) can be obtained by the equation of (Silva, Junior, Tonelli & Martins,2014):

$$Er = f_c \times PCI \qquad (9)$$

Where fc is a factor that represents the loss of energy from ashes and from radiation which corresponds to the value of 0,97. For the measurement of the electric power P(MW), obtained from the burning of urban solid wastes, the following formula is utilized, as described by (Silva *et al.*, 2014):

$$P = n_g \times n_t \times f_u \times M(t) \times PCI \qquad (10)$$

P: Electric Power (MW)
ng:Efficiency of the electric generator = 0,98
nt:Efficiency of the thermal machine = 0,33
fu:Utilization factor = 0,9
M(t): Incineration rate (kg/s)
PCI: inferior calorific value of the wastes (MJ/kg)

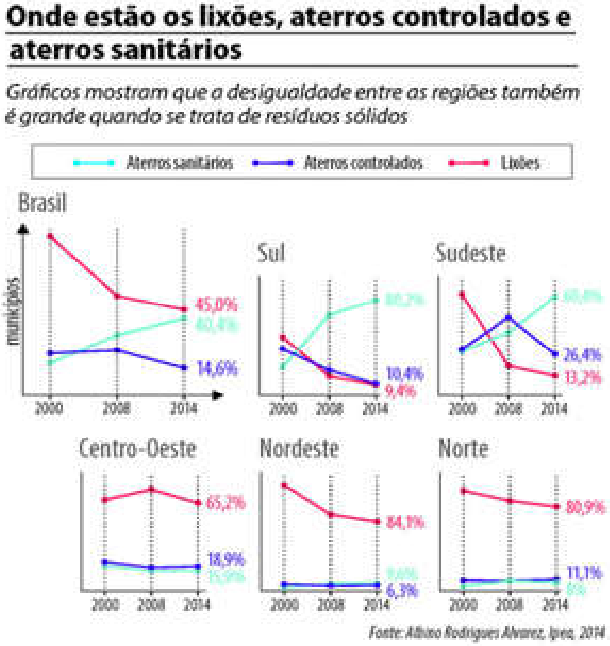
Estimation Methodology of the energy recovery from the recycling of wastes. As for recycling, we will use as reference the studies from the technical note 18/14, from the EPE (2014) Energy Research Office, which compares the main methodologies for the measurement of the energy needed from the extraction of the material for the industrialization process. By doing so we obtained the capacity of energy recovery in kWh/kg, which should be multiplied by the amount in kg of recycled material, considering the type of recycled material and the analysis of the lifespan of the product.

Theoretical framework

Management of solid wastes: Urban solid wastes (USW) are popularly known as garbage, they are the wastes generated by the disposal of materials that don't have any further use, undesirable and disposables, all of them characterized by being the result of human activities in the most varied areas of society. These wastesare divided into organic and non-organic materials.

Organic materials are those from biological origin (living beings), such as bones, food wastes, leaves, etc. And non-organic materials are originated commonly from minerals or are the result of the industrialization for human uses, like paper, plastic, metals, glass, etc.The final destination as well as the bad management of urban solid wastes results in negative impacts in the society, in the environment, in the health of the population, and so on. Over the years, this problem is expected to keep growing, as solid wastes become a key problem and one of the most complex issues in the modern environmental scenario.Up to some decades ago, it was very common the disposal of urban wastes in open air dumpsites, but as a result of numerous social and environmental impacts, these dumpsites are being replaced by landfills, which are already widely used in Europe and the United States.Landfills are spaces built with the specific end to serve as an appropriate disposal area for the garbage generated in the cities and solve the problems caused by the disposal of wastes in open air dumpsites.

Global scenario of waste reuse: All around the world there is a growing concern about climate change and the damages to the planet caused by human activities. The development of the society is at risk because everything can collapse as result of the shortage of the natural resources necessary for the future generations and their possibilities of living with quality (Schorr, Rogerio & Cenci,2015). That reality has led to an urgent effort to find more sustainable alternatives, including electric power, which is currently one of the most vital inputs for humans. More sustainable alternatives for energy generation are necessary to reduce the environmental impacts and ensure the supply of energy for the populations. One sustainable way of producing electricity is by using garbage. The alternative is already largely used in many countries.Bueno (2008as cited inSousa, Gaia & Rangel, 2010) informs us that the country with the biggest biogas installed capacity is Germany, with 1,7 GW and approximately 4.700 plants. The United States, England and Italy also boast expressive biogas installed capacities, with respectively 790 MW, 680 MW and 220 MW. Developing countries in particular have shown and increasing interest in this alternative for fuels. In this scenario Thailand stands out with 51 MW. The Brazilian energy potential found in this paper is of 311 MW, which is enough to place our country among the largest global electric power generators, and demonstrating how important this type of energy is for the national power system (Bueno, 2010 as cited in Sousa *et al*., 2010).In European countries, in the United States and in Japan (figures 1 and 2) generating energy from wastes is a reality since the 1980s. These countries alone process some 130 million tons of garbage, generating electric and thermal power in 650 plants.The European Union alone produces more than 10 mil MW from nearly 60 million tons of garbage every year in 400 power plants, which are capable of producing electricity for 27 million people (roughly the total population of Denmark, Finland and Holland combined). It is estimated that this market moves some 9 million Euros in the 15 main countries of the European Union. In North America, there are currently more than 1.700 power plants in operation which use some 100 types of different technologies (Bueno, 2010 as cited in Sousa *et al*., 2010).



(Source: Google Imagens, 2018).

Figure3. Distribution of dumpsites and landfills in Brazil

Present scenario of waste reuse in Brazil: In Brazil, the National Policy of Solid Waste law was launched in 2010. These norms regulate the final destination of solid wastes produced in Brazil, including urban wastes, serving as a regulatory framework that comprises the principles, goals, instruments and guidelines of the policy, which aims at the integration between the public entities involved, especially municipalities (MMA, 2010). According to the Brazil's Institute for Applied Economic Research (IPEA, 2012), many Brazilian municipalities still use dumpsites, which is a very inadequate way for disposing of these wastes. After the Policy was created, garbage disposal in Brazil has been done with much more responsibility. That resulted in an expressive increase in the number of landfills over the latest decade, aiming at giving these wastes a proper destination, solving the problems associated with open air dumpsites, which unfortunately are still very common especially in the North, North-East and Center-West regions of Brazil, as shown bellow in Figure 4.In order to find a solution for the problems caused by the incorrect destination for wastes, it is necessary that countries develop well structured and efficient policies for the management of wastes and this policies must take into account the generation of power through the usage of wastes as an alternative for input. In addition to the energy recovery contained in the garbage (recycling and composting), the energy generated by garbage becomes more and more attractive due to the possibility of the fast return of the investment after the creation of the Kyoto Protocol, through the trading carbon credits (MMA, 2010).Recycling and selective collection systems also play an important role regarding the conservation of energy, as they reduce the consumption of new materials through the reuse of recycled materials. According to the (IPEA, 2012), Brazil wastes approximately R$ 8 billion in non-recyclable materials, which reinforces the importance of policies that stimulate the collection and sorting of the wastes, reducing the levels of improper destination and creating job opportunities for lowincome populations.

In Brazil, there are many projects for the usage of garbage for the generation of energy, including incineration and the use of biogas and landfills. One example is the Usina Verde (green plant), located in the campus of the Federal University of Rio de Janeiro (UFRJ). This plant incinerates solid wastes and has a processing capacity of 30 tons a day, and installed potency of approximately 440 kW. The wastesare incinerated at a temperature of 1000ºC (on the first stage) for 30 minutes and on the second stage for the total conversion of the gases at a temperature of 1200ºC for 2 or 3 seconds. The gases generated after the incineration are neutralized after a closed-circuit washing. The exiting gases are sent to a heat recovery boiler, which creates water vapor to move the generators(Pacheco Costa*et al*., 2017).In Santa Catarina there is already an incinerator being tested in the city of Mafra by the company SerranaEngenharia. The equipment has an estimate generation capacity of 2 MW, transforming nearly 1 ton of garbage in approximately 100kg of ashes, and avoiding the need of the construction of a new area of 10.000 m² for the local landfill. According to OdairManrich, director of the company in an interview to the website G1, the investment was of approximately R$ 40 million (G1, 2017).

Selective collection in the city of Lages: Lages is a Brazilian city located in the state of Santa Catarina and has approximately 158.508 inhabitants (IBGE, 2017). The city counts on daily garbage collection services done by the company Serrana Engenharia, and all urban wastes are sent to the landfill located in the District of Índios, According to data from the Municipal Department of Environment. According to data provided by the Department of Environment, the disposal average is of about 90 tons a day or 2.700 tons a month during the year. The city also counts on a selective collection system carried out by the recyclable material collectors cooperative - Cooperlages - which cover the entire city; there are also other private groups like the Renascer da Cidadania and approximately 500 waste pickers in Lages (PML, 2017). The landfill of Lages was inaugurated in May 19th, 2006, when the old dumpsite was closed, with the objective o giving a proper destination for the urban wastes generated in Lages. A landfills receives on average 3700 tons of garbage monthly. It also receives wastes from other 12 municipalities of the region, totaling 3800 tons every month (PML, 2017).Due to the deficiency in the collection of recyclables, especially when the operation was starting, a great amount of materials were disposed in the landfill, which shortened a little it is lifespan.

(Source: Moura,2014)

Figura 4. Landfill in Lages

Tecnologies for the generation of energy by using garbage: The knowledge of the main technologies for the generation of energy is necessary to measure the potential of solid urban wastes for the generation of energy. It is also vital for the understanding of the importance of recycling for the conservation of energy and the measurement of the data to corroborate this fact.

Energy generation at the biogas landfill: Using landfills for the production of biogas and electric power is a sustainable way of avoiding the pollution generated by methane, is view that this element is highly polluting and is one of the causes of the greenhouse effect (IBAM, 2001).According to Figueiredo (2011), the garbage disposed in landfills undergoes an aerobic decomposition in a first moment, when the wastes are dumped on the soil; after covered the amount of O_2 starts to decrease and the anaerobic decomposition process starts, originating the gas composed mainly of methane and carbon dioxide. Buswell& Mueller, in 1952, created the following equation for the measurement of the anaerobic decomposition:

$$C_nH_aO_b + \left(n - \frac{a}{4} - \frac{b}{2}\right)H_2O \leftrightarrow \left(\frac{n}{b} - \frac{a}{8} + \frac{b}{4}\right)CO_2 + \left(\frac{a}{8} + \frac{n}{2} - \frac{b}{4}\right)CH_4 \quad (11)$$

The gas has a percentage of methane that ranges from 40% to 75% (CASTANON, 2002); this variation occurs due to some factors such as the amount of organic material present in the garbage disposed in the landfill. The calorific value of the gas makes it possible for its burning for the generation of energy, consequently reducing gases emissions that cause the greenhouse effect. In the tablebelow we can see the amount of gases contained in the biogas.

Table2. Composition of biogas

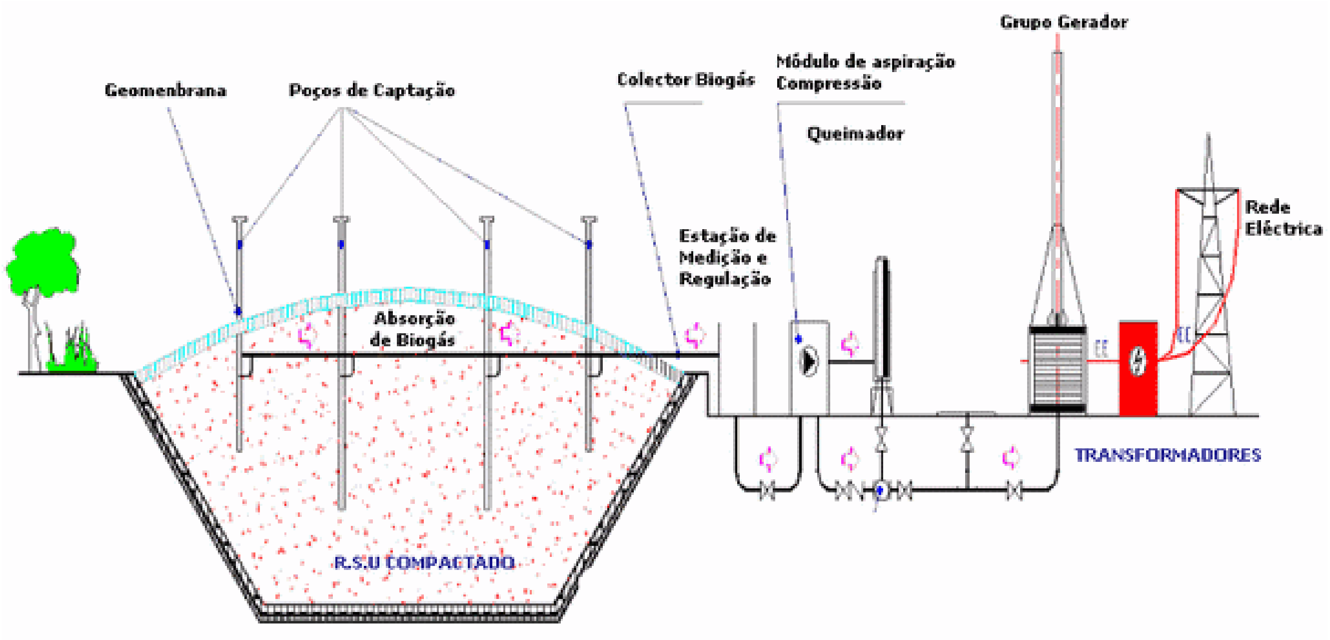
Gas	Percentage (%)
Methane ($\mathbf{CH_4}$)	40 - 75
Carbon dioxide ($\mathbf{CO_2}$)	25 - 40
Nitrogen (N)	0.5 - 2.5
Oxygen (O)	0.1 - 1
Sulfidic Acid ($\mathbf{H_2S}$)	0.1 - 0.5
Ammoniac ($\mathbf{NH_3}$)	0.1 - 0.5
Carbon monoxide (CO)	0 - 0.1
Hydrogen (H)	1 - 3

(source: Castanon, 2002)

A biogas plant operates by extracting the gas from the landfill, treating it and finding uses for it. The collection is usually done by vertical drilled pipes, from where it is sucked by a compressor. This process if followed by the treatment of the gas for the removal of impurities such as CO_2, which is reduced to make possible the use of smaller storage reservoirs, leaving only the methane for the burning. The gas can then be used in turbo-generators or a boiler for the production of heated water to be used in households or industries.

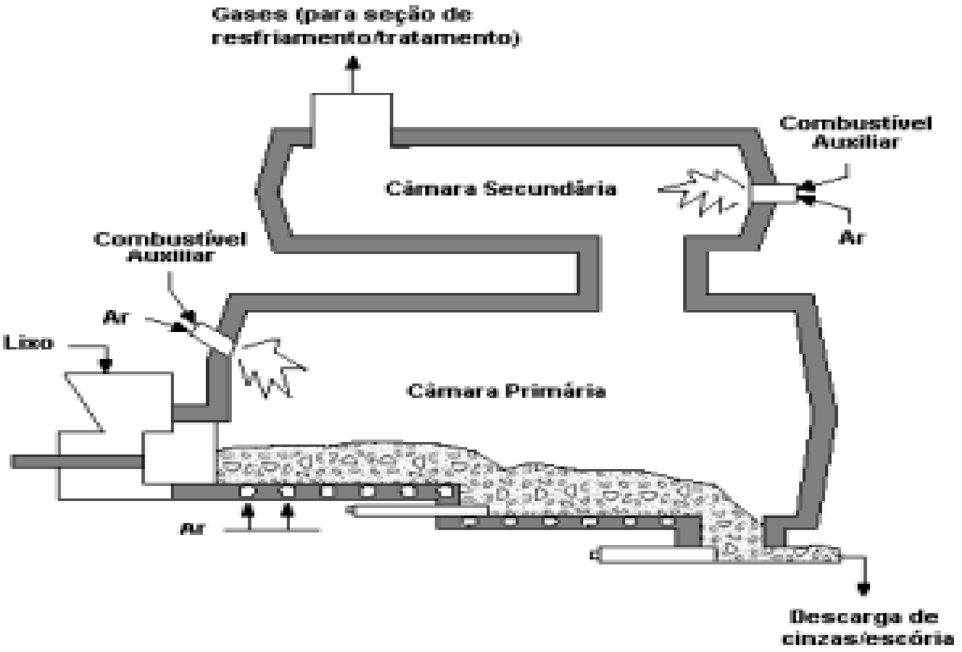
Generation of energy from the incineration of garbage: One of the ways of managing urban solid wastes is the controlled incineration of garbage, which is already largely used in Europe, the United States and Japan, because in addition to the energy generated it also reduces the need of the construction of new landfill. For the thermal treatment of the garbage there are technologies that prevent that high amounts of pollutants be launched into the atmosphere, through a heating system for high temperatures and cleaning of combustion gases (Ribeiro, 2010). Due to the similarity between the processes on electric power generation from the incineration of USW and conventional power plants, a capacity of generation depends directly on the calorific value of the material being used.

This system can supply between 350 and 600 kWh/t from the USW. The following table shows the calorific value of materials usually found in urban solid wastes and we can also see that organic wastes tend to have lower calorific values (EPE, 2014).The first stage of the incineration process is the sorting of the collected materials for the removal of recyclables (metals, glass, etc.); then the wastes are sent to the incineration process at high temperatures for obtaining gases and particulate matter, which undergoes a new burning process until the complete combustion of the resulting gases at an even higher temperature than that of the first stage, the temperatures vary from 750ºC to 1200ºC (Henriques, Oliveira & Costa, 2003).The resulting gases from the combustion are highly pollutant and need to pass through other processes, such as scrubbers, electrostatic precipitators and filter for the removal of polluting, and only then they are released to the atmosphere. The energy is generated from the heat from hot gases, along with the usage of economic superheaters for a further increase of the process efficiency.



(Source: Algar, 2017)

Figure 5. Layout of a Landfill Biogas Plant



(Fonte: Henriques et al., 2003).

Figure 6. Illustration of a waste combustion chamber

The heat is then used for the generation of vapor, which will serve for obtaining electric power (Henriques *et al*., 2003). The volume of ashes is of about 10% of the volume of the waste incinerated, these ashes are sent inert waste landfills or they can be used in civil construction works.

Energy recovery by recycling: Recycling is the process of breaking down and re-using materials that would otherwise be thrown away as trash. Through recycling waste materials are converted into new materials and objects. As an example, used paper, glass, aluminum and copper can be reused as raw materials in the same industries where they were first used. Recycling must be a priority because its energy balance is much more favorable than burning these materials. Recycling also helps to significantly reduce the amount of materials that would otherwise be disposed of in landfills, increasing their lifespan.But for recycling initiatives to work effectively it is necessary to invest in waste collections systems, proper spaces where the garbage can be sorted and classified, facilitating the logistics and avoiding the wasting of recyclables. In addition to its environmental benefits, recycling can also generate jobs and income, especially through the creation of cooperatives and recycling centers where waste pickers can work safely, creating better conditions of work and with better pay (MMA, 2010).

Another significant benefit from recycling is energy conservation, which is the reduction of the consumption of energy for the transformation of raw materials in products for human consumption, considering that raw materials need far more energy to be transformed. One example is aluminum, where 1 kg of recycling avoids the extraction of 5 kg of bauxite, which needs 20 times more energy for its transformation into primary aluminum, according to data from the technical note 06/08 from the Energy Research Company (EPE, 2008).The table below shows the energy conservation from the recycling of the most common wastes in some countries of the world: In spite of the values in kWh/kg conserved in addition to the other benefits from recycling, some details can make the idea unviable, because it requires a certain degree of homogeneity for not losing its reuse potential or result in an increase in the processing costs, other factors that must be taken into account are the degradation of the materials and the number of times the materials have been recycled(Pacheco Costa *et al*., 2017).

RESULTS AND DISCUSSION

Energy potential from biogas in the landfill: By the analysis of the results obtained from the methodology we were able to estimate the amount of methane that can be generated at thelandfill and subsequently calculate the energy potential that this amount will be capable of generating.

In the table below we can estimate the amount of methane that will be generated as from 2017 on:With the result from the amount of methane available we can calculate its energy potential, power values and available power available as from 2017. The data are shown in table 4:

Energy potential from the incineration of waste: For the measurement of the energy potential from incineration we calculated the inferior calorific value (kcal/kg), which resulted in 3237,4 (kcal/kg) and made it possible the calculation for the estimation of the electricity potential:

Energy conservation potential by recycling: In terms of numbers, after an interview with members of the Cooperlages and the 'Renascer da Cidadania' group, it was found that the amount of urban wastes collected in Lages is far below what could be collected; on average the cooperative collects 240 tons a year and the Renascer group other 78 tons a year. These numbers are significant, if we take into account that the city has more than 500 waste pickers registered. In this way, collecting wastes is an important economic activity, but even that being the reality, most of the city waste still goes to the landfill, reducing its lifespan. With a construction cost estimated at R$ 54 million (Abrelpe, 2015), and the overload of recyclables, the lifespan is of about 12 years, which increases excessively operational costs. An investment of R$ 54 million would generate a present value of R$ 7.884.966,86, after 25 years, considering a minimum acceptable rate of

Table 3. Calorific value of SUW – 2005

Materials	(kcal/kg)
Plastic	6301
Rubber	6780
Leather	3629
Textiles	3478
Wood	2250
Wood	1311
Paper	4033

(Source: EPE, 2014)

Table 4. Potential for electricity conservation from recycling of packages kWh/kg - 2008

Material	Brazil	United States		Australia
	Calderoni	Morris	EPA	Wamkem ISE
PaperandCardboard	3,51	1,75	2,95	1,37
Plastic (Including PET)	5,06	5,55	15,39	5,91
Glass	0,64	0,08	0,62	1,25
Package Longa vida	3,51	1,75	4,96	1,37
Metals (Aluminun, steel)	5,3	3,25	5,85	2,67

(Source: EPE, 2008)

Table 5. Annualmethaneflow

Year	Flow (10^3 m^3/year)	Collectedmethane (10^3 m^3/year)
2017	1.462	1.097
2018	1.544	1.158
2019	1.622	1.216
2020	1.695	1.271
2021	1.765	1.324
2022	1.832	1.374
2023	1.896	1.422
2024	1.958	1.468
2025	2.016	1.512
2026	2.073	1.555
2027	1.919	1.439
2028	1.777	1.333
2029	1.645	1.234
2030	1.523	1.143
2031	1.411	1.058
2032	1.306	979
2033	1.209	907

Source: Prepared by the authors (2017).

Table 6. Power, energy generated from biogas – 2017

Year	Power (MW)	Power (m^3/h)	Energy (kWh/month)	Price/month
2017	1.235	141	101537	49600,97
2018	1.305	148	107232	52382,97
2019	1.371	156	112649	55029,26
2020	1.432	163	117719	57505,92
2021	1.491	170	122581	59880,79
2022	1.548	176	127234	62153,89
2023	1.602	182	131679	64325,2
2024	1.654	188	135985	66428,66
2025	1.703	194	140013	68396,42
2026	1.752	199	143972	70330,24
2027	1.622	185	133276	65105,52
2028	1.502	171	123414	60287,91
2029	1.390	158	114247	55809,58
2030	1.287	147	105774	51670,51
2031	1.192	136	97995	47870,71
2032	1.104	126	90703	44308,39
2033	1.022	116	83966	41017,49

Source:Prepared by the authors (2017)

Table 7. Power, energy generated and values for incineration – 2017

Year	Power (MW)	Waste rate (kg/s)	Energy (kWh/month)	Price/month (R$)
2017	2,62	0,94	215,29	105,26
2018	2,65	0,95	217,47	106,32
2019	2,67	0,96	219,66	107,39
2020	2,7	0,97	221,88	108,48
2021	2,73	0,98	224,12	109,57
2022	2,75	0,99	226,39	110,68
2023	2,78	1	228,67	111,8
2024	2,81	1,01	230,98	112,93
2025	2,84	1,02	233,32	114,07
2026	2,87	1,03	235,67	115,22
2027	2,9	1,04	238,05	116,38
2028	2,93	1,05	240,46	117,56
2029	2,96	1,06	242,89	118,75
2030	2,98	1,08	245,34	119,95
2031	3,02	1,09	247,82	121,16
2032	3,05	1,1	250,32	122,38
2033	3,08	1,11	252,85	123,62

Source: Prepared by the authors (2017)

return (MARR) of 8%; which the reduction of the lifespan the present value will be of R$ 21.444.142,97, that is to say, an increase of 172%.

Economic feasibility: Bearing in mind the investment in an incineration plant is of about R$ 45 million and that the investment in a plant to harness the energy potential of the biogas from a landfill is of about R$ 4 million (Abrelpe, 2015), we can clearly see that this amount is far inferior than the R$ 54 million used in the construction of a new landfill, not to mention all the money that is wasted along the process. All the materials that are not recycled mean less money for recyclable material collectors and they remain underexploited, as they could otherwise be used for the generation of energy, saving economy resources for the city by incineration and by the production of biogas. Not to mention that trading carbon credits also generates money. By calculating the economic feasibility of the construction of a biogas plant at a landfill, it was found that the results were very good. As a parameter, we used a social, environmental and ecologic project that has a payback of 5 years, 11 months and 11 days, a Net Present Value VPL of R$ 4.080.897,81 and an Internal Rate of Return (IRR) of 15,70%. We considered an interest rate of 4%, which is the standard rate for this type of project. Also, in order to attain a simpler overview of the issue, we didn't include in the calculation the inflation and currency devaluations. Our study has shown that project is economically viable and such initiatives should be approved for implementation.

It's important to note that this work does not assess what could be gained with the production of fertilizers. If we did include this factor, the estimate gains could be reduced by half, which would considerably increase the benefits for the society and the economy. In terms of the energy production gains of incineration, they are relatively small, but that alone is not enough to make of the construction of the plant an inviable project. But if we take into account that an incineration plant will reduce the need for new landfill, at a cost of R$ 54 million, we still think that the alternative is much more viable, as the construction of a plant would cost R$ 45 million, which means savings 20 percent. Not to mention that price of land to be bought for the landfill and the pollution impact.

Conclusion

In this work it has been demonstrated theoretically, based on the data and calculations from the bibliographic research, the potential for the generation of energy in Lages using solid urban wastes as fuels. We focused especially on the biogas that can be produced in the landfill and the benefits of incineration, but we also highlighted the importance of recycling as a priority for making it viable both the energy generation and the financial returns from the correct handling of urban wastes.As for the production of biogas, we found the most promising and expressive results in the generation of energy, reaching a maximum amount of 43.972 kWh/monthly (during the last year of operations of the landfill), which would be enough to supply energy to 550 households (each consuming an average of 260 kWh/monthly), which makes of the project a very attractive alternative. As for incineration, the results were less expressive, reaching a maximum amount of 252 kWh generated monthly. This is mostly caused by the low calorific value of solid urban wastes and the high costs of building this type of plant, and due to the higher polluting potential of the gases from the incineration of the garbages. On the other hand, this model is very efficient in the reduction of the wastes and, as a consequence, it reduces the need for the construction of new landfills. As for recycling, we found that there is the need of an stratification of the data by the environmental control agencies and recycling centers, as they didn't have have data by materials, but only total quantities. For future studies there is the need of researches that make possible the increase of the calorific value of the wastes, as well as the development of more efficient programs and policies for recycling. It is also important to keep improving control mechanisms and data management on the energy scenario of urban solid wastes, as it has a great potential for sustainable development.

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