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ECONOMIC FEASIBILITY OF IMPLEMENTATION AND INSTALLATION OF PLANT INCINERATOR WITH ENERGY UTILIZATION SYSTEM FOR THE REGION OF BAURU

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Abstract. *This article discusses the incineration of Municipal Solid Waste (MSW) as a way of obtaining energy and as a way to properly dispose of solid waste generated in the region of Bauru. In this context, was proposing the formation of inter-municipal consortium as a mechanism for the creation of an incineration system power co-generation.*

The study addresses the economic feasibility and installation of the incinerator plant with energy recovery system, making simulations on capital costs for construction and maintenance of large-scale incinerators. Adopts the following methods for analysis: Net Present Value (NPV), Internal Rate of Return (IRR) and Payback. The data show that the profitability of the project depends on the price of electricity charged by the market, and the prices for waste disposal in landfills. A higher return is possible when both conditions are present and the viability of the project depends largely on the revenue from the sale of energy.

Keywords: *Economic Viability; MSW Incineration; Co-generation Energy by MSW Incineration*

1. INTRODUCTION

In the context of the issues related to environmental protection, the waste problem occupies a prominent place in the management of environmental resources.

The concern regarding waste management and procedures have been integrated management that became part of the management policies in order to avoid irreversible changes to the environment and humans. One solution was to deposit such waste in landfills, which often is far from happening in most municipalities.

According to 2011 data from the Brazilian Association of Public Cleaning (ABRELPE), the comparison between the data on the southeastern Brazilian reveals that there was an increase of 2.6% in the environmentally sound disposal in landfills, however, 27.8% of waste collected in the region, corresponding to 26000 tons per day, are still destined for dumps and landfills, the environmental point of view does not have the number of systems required to protect the environment and public health. On the other hand, if the implementation of these landfills has been one of the solutions, it does not guarantee the solution to environmental problems, because when deployed improperly cause pollution of soil, air and water.

In turn, the generation of energy from renewable and low environmental impact, and the creation of mechanisms for better use of the areas of disposal of municipal solid waste (MSW) have been encouraged by the government. Research in this area has followed such a stimulus, resulting in a series of studies and articles related to the subject.

In this context, the choice of incineration of waste in appropriate facilities that have efficient systems for wastewater treatment, has been one of the solutions adopted by many countries, for example, in the countries of the European community. According to the information booklet Energy Recovery 2012, with the development of forms of thermal treatment of municipal solid waste in Europe increased by 34% while the target areas for landfills declined 33%.

Thus, it is proposed to study the economic feasibility of municipal solid waste incinerators with energy recuperation in a consortium of municipalities in the region of Bauru. The evaluation will be performed from technical economic indicators, Net Present Value (NPV), Internal Rate of Return (IRR) and Payback.

2. LITERATURE REVIEW

Incineration is an alternative for treatment of municipal solid waste, and may be defined as the thermal process in which the solid waste is oxidized with excess amounts of oxygen, Tchobanoglous (1996).

Hauser (2007), states that incineration is one of the most effective methods in the reuse of waste, either to reduce its potential harmful to the environment, such as the possibility to use for generating electricity.

The incineration of waste is characterized as the efficient method to reduced methane emissions, besides replacing the production of energy from fossil fuels, Poletto (2008).

In Brazil there is a distrust of the use of incineration methodology to the garbage, this is due to use of the outdated equipment and without proper maintenance, in the past.

Incineration, according Kreith (1994), provides many advantages and can be cited: reducing the volume and weight of waste, immediate reduction of waste, requiring no long stay in landfill. The waste may be incinerated in nearby or strategic locations and gaseous emissions can be effectively controlled not implying environmental risk to the atmosphere. The products generated in burning, the ashes, are inert and can be recovered in the process.

The combustion process also has some disadvantages that include: the high investment cost, the need for skilled labor and that not all materials can be found in the MSW incinerator.

Are currently employed various technologies for waste incineration. According to Silva (1998), a modern plant of MSW incineration comprises: septic waste disposal bucket gripper for feeding the combustion chamber, feeder grids combustion chamber, the combustion chamber (where the residues are burned), post-combustion chamber, boiler energy recovery, treatment gases (particulate separator, bag filter, wet scrubber, electrostatic filter), system exhaust and gas dispersion (chimney), treatment of wastewater generated in the gas cleaning, collection and pre-treatment of wastewater solids (ash and slag generated in the combustion chambers), the receptor for solid material (landfill), facility control, automation and others.

Energy recovery during the thermal treatment of waste can aim: generating electricity and / or steam, cooling water by absorption refrigeration cycles and cogeneration system.

Different incineration technologies have been developed to treat various kinds of waste. In general the units are used to incinerate waste solids, liquids and sludge, Poletto (2008). The classification systems used for incineration is made according to the shape of the chamber and the combustion process carried out among the different technologies used for combustion of MSW include: systems with dual-chamber fixed, rotary drum, fluidized bed systems and plasma.

For Hauser (2006), the first step is receiving the MSW and the selection of recyclable materials: MSW received is stored in a silo that feeds a conveyor. Before incineration, the waste is dried using part of the surplus heat from the process. Garbage selected and dried is called Fuel Refuse Derived (FRD).

The second step of the process is the incineration and energy recovery: FRD is directed to the combustion chamber, which operates at a minimum temperature of 850 °C. The ash produced is removed using a stream of water at the bottom of the chamber. The flue gases are led into post-combustion chamber, where the temperature is above 1000 °C and an excess of oxygen to ensure complete oxidation.

The hot gases generated are led into a heat recovery boiler, where it creates pressurized steam to drive the turbo-generator which supplies electricity. After the process of generating the water vapor is condensed and returned to the initial process.

The next step is the washing of flue gases. Combustion gases are led to the washing equipment. The first step is to spray water in the flue gas and to reduce the temperature to dissolve the acid gases. Then, the gas is led through a pipe crossed by the water curtains produced by propellers in motion. The passage of exhaust gas through these curtains of water leads to their purification. Then the gases are dried and freed through the chimney.

The amount of waste to be incinerated, the calorific value of the fuel material and other combustion parameters, determine the type of technology to be adopted, Saffer (2011).

Due to the high investment costs and operation, power plants Waste to Energy (WTE) present difficulties for developing countries especially where capital and skilled labor are scarce. As the incineration of MSW is significantly more expensive than the ground, the costs should be offset by the sale of recovered energy. Therefore, the characteristics of the energy sector are important in the consideration of WTE plants are desirable and price agreements for long term. The fact that the recent WTE plants in developing countries can be installed as a Clean Development Mechanism projects (CDM) offer an additional source of revenue, but the risks must be carefully evaluated.

According Maranho (2008), there are currently incinerators in the market that have high burning efficiency with low fuel consumption and low emissions. Conservatively, the gases leaving the second combustion chamber, while the combustion efficiency, still need further treatment, which in many cases acts as an additional safety precaution. Maranho (2008) examined the feasibility of generating electricity from the combustion of municipal solid waste (MSW) in Bauru and its administrative region. The main objective was to collect data on the quantity and composition of material collected and estimates the potential energy to be generated. Therefore, we analyzed the daily total collected in the aforementioned region obtained from the Annual Report of CETESB. Was adopted the hypothesis of the constitution of an inter-municipal consortium, and that Bauru would be the best option to host the regional plan, to be the largest generator and be located in a central position in the region.

For complete combustion of the MSW results, was used the software Combust important tool to simulate the process and calculate the compositions of the gases generated.

Results showed that could be obtained about 355 MWh/day of electric energy, with 12.8 MWh/day used for the transport of MSW to Bauru, or the net energetic potential is 342.2 MWh/day. When considering the separation of plastic, paper / cardboard for recycling, the net energetic potential dropped to 228 MWh/day. As expected, there is a substantial reduction in energetic potential when implementing the recycling of combustible materials. Thus, one can say that the energetic analysis shows the biggest advantage of the combustion of MSW without recycling of combustible materials.

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An investment in large-scale incinerators requires the insertion of new technologies, which allow obtaining a better use of natural resources, as well as integrated management of solid waste. For this it is necessary to do studies to optimize the efforts of investments.

Overall, the survey of the costs of the plant, and the study on the feasibility of implementation are aspects that can assist in the analysis of the decision-making process of the implementation of inter-municipal consortium composed of the municipalities of the administrative region of Bauru city.

3. MATERIALS AND METHODS

It was chosen as the object of study, a possible joint venture between the cities of the administrative region of Bauru, on the basis in the distribution of the regional sections of CETESB, plus three more municipalities that are located within a coverage area (São Manuel, Areiópolis and Botucatu).

It was used data on estimates of capacity to generate energy from burning MSW of the region of Bauru to obtain results concerning the financial profitability.

The data relating to investment have been raised from different sources, so was considered the average values presented in other work on the same theme.

In analysis of the financial viability was used the NPV and IRR methods. The method NPV, also called Net Annual Value method, is designed to determine a value at the initial time from a flow box formed by a series of revenue and expenditure, Hirschfeld (2009).

The NPV of cash flow is therefore the algebraic sum of the present values involved in this cash flow, and can be represented by Equation (1). This method is one of the most used in the valuation of investments by getting the value of output in current terms, given an interest rate, and be free of glitches.

$$NPV = \frac{F_1}{(1+i)^1} + \frac{F_2}{(1+i)^2} + \cdots + \frac{F_n}{(1+i)^n} - F_0 \qquad (1)$$

When:

NPV= net present value of a cash flow.
n = number of periods involved in each element of the series of revenue and expenditure of cash flow.
F_n = each one of the various values involved in the cash flow, and that occur in n.
i = interest rate comparison or hurdle rate, also called rate equivalency rate expectation or even discount rate.

The Internal Rate of Return (IRR) is defined as the rate that makes the present value of the benefits and is equal to the values of the updated costs. Being a method that depends exclusively on the cash flow of production systems, is a relative measure that corresponds to the rate increase “i” the value of investment over time, given the resources required to produce the revenue stream.

The IRR calculation is similar to the net present value and sets a discount rate that equates the NPV to zero to estimate the Rate of Return on Investment, according to Equation (2), Hirschfeld (2009).

$$IRR = \frac{F_1}{(1+i)^1} + \frac{F_2}{(1+i)^2} + \cdots + \frac{F_n}{(1+i)^n} - F_0 = 0 \qquad (2)$$

When:

IRR = Internal Rate of Return.
n = number of periods involved in each element of the series of revenue and expenditure of cash flow.
F_n = each of the various values involved in the cash flow and that occur in n.
i = interest rate comparison or hurdle rate, also called rate equivalency rate expectation or even discount rate.

4. Economic Assessment Model

The economic assessment model built and applied in this work aims to identify the economic feasibility of a project to generate electricity using technology of the WTE, operating in co-generation, using fuel derived from waste (FRD).

The calculation methodology is based on the realization of the statement of cash flows. The cash flow of the investment is considered constant over the project, this means that for the purpose of simulations considers that no changes occur over the period analyzed.

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The cash flow built into model considers the initial investment and the annual net income from the perspective of design life of 25 years. Based on this cash flow is carried out to was calculate the rate of Return, Net Present Value of Investment, and other indicators.

Cash flow is the assessment of monetary contributions over time to a box already constituted symbolic, Hirschfeld (2011). It is agreed that the cash inflows are positive and negative outputs.

To construct the model was adopted the following variables and assumptions: the default value for the sale of electricity generated by the project for which it is adopted the marketing value of R$ 170.00 per MWh, the plant is in the range typical adopted production with incineration of 8000 hours / year, the economy with the thermal treatment of MSW is computed as operating income, with standard fare of R$ 120.00 per ton processed, technical specifications and the initial investment cost according to Tab. 3.1, the calorific value of MSW is based on the theoretical framework, was used those adopted by Maranho (2008).

The initial investment required for implementation of the project includes planning, construction and implementation of a power plant with a processing capacity between 350 and 640 t/d (this mass that enables energy recovery), considering the characteristics of the calorific value of the material to be incinerated. In the study it is assumed that the capital investment is taken from the National Bank of Economic and Social Development (BNDES). Specifically for the implementation of projects for landfills, and covering a solution for waste treatment (composting, "mass burning", energy use, waste blending plants, waste processing into raw materials, among others), the maximum participation the financial agent may reach 100% of the eligible items (BNDES, 2012). It was considered that the costs related to the acquisition of the land will be the responsibility of government, i.e., the land will be donated by the cities of the consortium for the project implementation.

To get the revenue from the implementation of MSW incinerator were considered market prices. The parameters that make up the cash flow of the project, with mean values of investment are presented in Tab. 3.1.

The financing conditions include interest rate of long-term basic pay, plus the BNDES and the hazard ratio with time grace period of 24 months and compounded annual interest, the Constant Amortization System (SAC) and benefits with long grace period of two years to begin payments.

Table 3.1 Amounts related to investment

Item	Scenario Investment
Initial investment (R $)	232.400.000,00
Minimum Capacity (t / d)	350
Capacity (t / d)	640
Net efficiency of the plant (%)	26
Total Power (MW)	15
Availability (hours / year)	8000

Source: Saffer (2011)

Operating and maintenance costs were calculated based on plant information and parameters similar to those used in this study, for example the work done by Saffer (2011), where the cost of maintenance and the fixed overheads are estimated at R$ 144.085,00 per month. Such expenses include taxes and variable charges, operating expenses with 35 people to operate the plant and maintenance expenses. Was adopted the assumption that all operating costs will remain stable over the project.

An evaluation of the project activity as the Clean Development Mechanism (CDM), estimated to reduce emissions of greenhouse gases resulting from mitigation activities greenhouse gases according to the methodology employed by Hauser (2007), in which the emission factor from the baseline emission factor is possible to calculate the Factor of Mitigation (FM), which quantifies the reduction of $\mathbf{CO_{2e}}$ per ton of MSW.

For Hauser (2007) evaluation of the values presented in this study serve as a reference for the FM least 0.60, average 0.80 to 1.0 maximum. Thus, for calculating total emissions of greenhouse gases achieved in this study was worked with the minimum value for the mitigating factor.

Make projections for the medium and long term price of electricity is not easy task, as the production and distribution are tightly regulated in Brazil and the offer depends on the climatic conditions, Hauser (2007). Considering the alternatives to determine the price, this study used a standard average value of R$ 170, 00, and simulations were

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made for the standard price fluctuated between +20% and -20% of the value. Thus, it was considered the revenues from the sale of each MWh of electricity from the proposed scenarios in Tab. 3.2.

Table 3.2- Scenarios proposed for the simulations.

Scenarios	**investment**	**thermal destruction**	**normative value**
1	Original	Original	Original
2	Original	Original	+20%
3	Original	Original	-20%
4	Original	+20%	Original
5	Original	+20%	+20%
6	Original	-20%	-20%
7	+20%	Original	Original
8	+20%	Original	+20%
9	+20%	Original	-20%
10	+20%	+20%	Original
11	+20%	+20%	+20%
12	+20%	+20%	-20%

5. RESULTS AND ANALYSIS

The total emissions of greenhouse gases (**CO_{2e}**) avoided annually with the incineration of 550 ton/day of the MSW, will be approximately 111.674 tons of **CO_{2e}**, which will generate an annual revenue R$ 3.512.005, 20 from the sale of carbon credits. This value was calculated from the mitigating factor and considering the price the trader of carbon credits 12 EUR.

Assuming real rate of interest of 9.71% per annum for the BNDES financing, so the default value considered in the study to project capital is R$ 232.400.000,00, and the total investment pattern would be of R$ 295.775.480,00.

Based on the monthly revenue of the project, was calculated the values for annual contributions of the project, considering the different scenarios. The Table 4.1 summarizes the estimates of operating earnings from the different scenarios proposed.

Table 4.1-Values of annual revenue resulting from the project

Scenarios	**Sale of energy**	**Destruction thermal**	**Credit carbon**	**Total revenue**
1	R$ 19.391.333,33	R$ 22.000.000,00	R$ 3.512.005,20	R$ 44.903.338,53
2	R$ 23.269.600,00	R$ 22.000.000,00	R$ 3.512.005,20	R$ 48.781.605,20
3	R$ 15.513.066,67	R$ 22.000.000,00	R$ 3.512.005,20	R$ 41.025.071,87
4	R$ 19.391.333,33	R$ 26.400.000,00	R$ 3.512.005,20	R$ 49.303.338,53
5	R$ 23.269.600,00	R$ 26.400.000,00	R$ 3.512.005,20	R$ 53.181.605,20
6	R$ 15.513.066,67	R$ 17.600.000,00	R$ 3.512.005,20	R$ 36.625.071,87
7	R$ 19.391.333,33	R$ 22.000.000,00	R$ 3.512.005,20	R$ 44.903.338,53
8	R$ 23.269.600,00	R$ 22.000.000,00	R$ 3.512.005,20	R$ 48.781.605,20
9	R$ 15.513.066,67	R$ 22.000.000,00	R$ 3.512.005,20	R$ 41.025.071,87
10	R$ 19.391.333,33	R$ 26.400.000,00	R$ 3.512.005,20	R$ 49.303.338,53
11	R$ 23.269.600,00	R$ 26.400.000,00	R$ 3.512.005,20	R$ 53.181.605,20
12	R$ 15.513.066,67	R$ 26.400.000,00	R$ 3.512.005,20	R$ 45.425.071,87

In order to ascertain the financial result in the project and compare different scenarios of implementation of the project were made some simulations and assessments. It was used data on the annual costs practiced in similar projects, consisting of the expenditures with hand labor, maintenance and operation. The analyze based on the assessment of the cash flow factors, with quantitative methods, had an intention to determine the potential benefits for the project.

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The construction of the model of economic analysis of a project requires the development of a cash flow and use of data considered certain and constant, however, this rarely happens, because these data are estimates that attempt to translate an image of reality.

According Lapponi (2007), although some projects are defined with great care is needed to develop the project NPV after being made an inquiry about the result before it is accepted.

The acceptance of the positive NPV project is also uncertain because it is based on cash flow formed by uncertain estimates. Although the results when taken to indicate the general ways a good decision.

Through different scenarios reproduces the uncertainty of the project, carried out a sensitivity analysis for different sets of variables that may affect the project. The values presented in this paper show that the project is formed by the initial cost, and a series of “n” returns generated from the period of Cash Flow (CF).

All predictions were made in real terms, i.e., currency of constant purchasing power. The Figure 4.1 and 4.2 shows, respectively, the results of the NPV and IRR obtained from the evaluation of cash flows for the scenarios simulated.

It was considered the hypotheses present deadlier to the sale price of the MWh of energy and was also used the possibilities of price for thermal destruction, considering the values adopted standards. The price of the initial investment was R$ 232.400.000, 00.

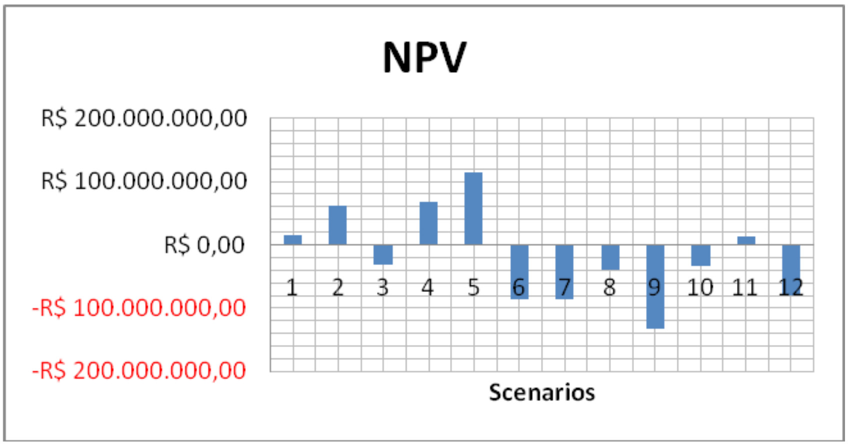

Figure 4.1: Results of the NPV to the scenarios presented

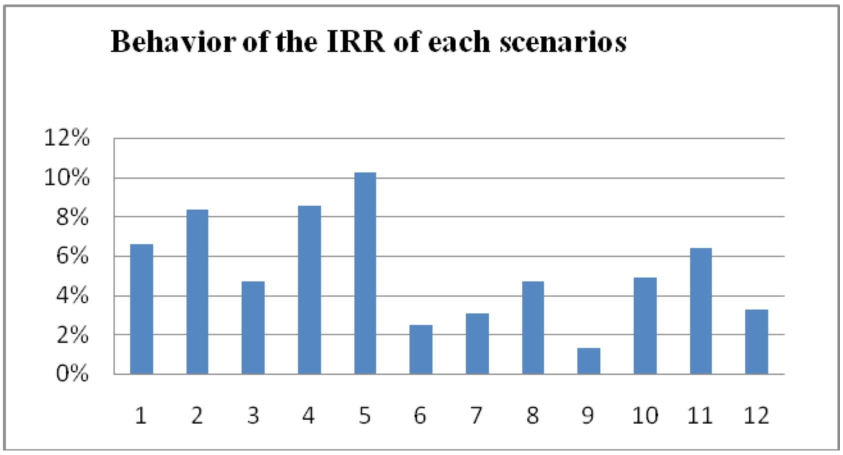

Figure 4.2: Behavior of the IRR to the scenarios presented

Through financial analysis it was found that the attractiveness of the project is possible in the simulations, i.e., demonstrated acceptable returns on investment, with the hurdle rate above 6%, and NPV of the project necessarily positive. The scenarios 1,2,4,5 and 11 indicate positively the realization of the project.

The Figure 4.3 represents the return time of the return of investment, i.e. the time required for the benefits may cover an investment costs. According Hirscheld (2012), the period of return is the determination of a period "n" in which the costs (C) are the same benefits (B). Thus, the cost subtracted Benefits should be equal zero, may be equivalent to NPV= 0, ie, the moment of return period "n" is the moment when the NPV = 0.

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The investment analysis involves decisions applying resources with long maturities, with the goal of providing adequate return on investment requires an estimate of the recovery time of the investment, which will be obtained with the time analysis of return on investment, this the Payback.

The Figure 4.3 shows the evolution of the best option Payback was 4.37 years (scenario 5). In this period the investment would be recovered. Still, it seems that the NPV for the period mentioned, R$114.340.413,50 is a positive value, with a rate of return above the 6%.

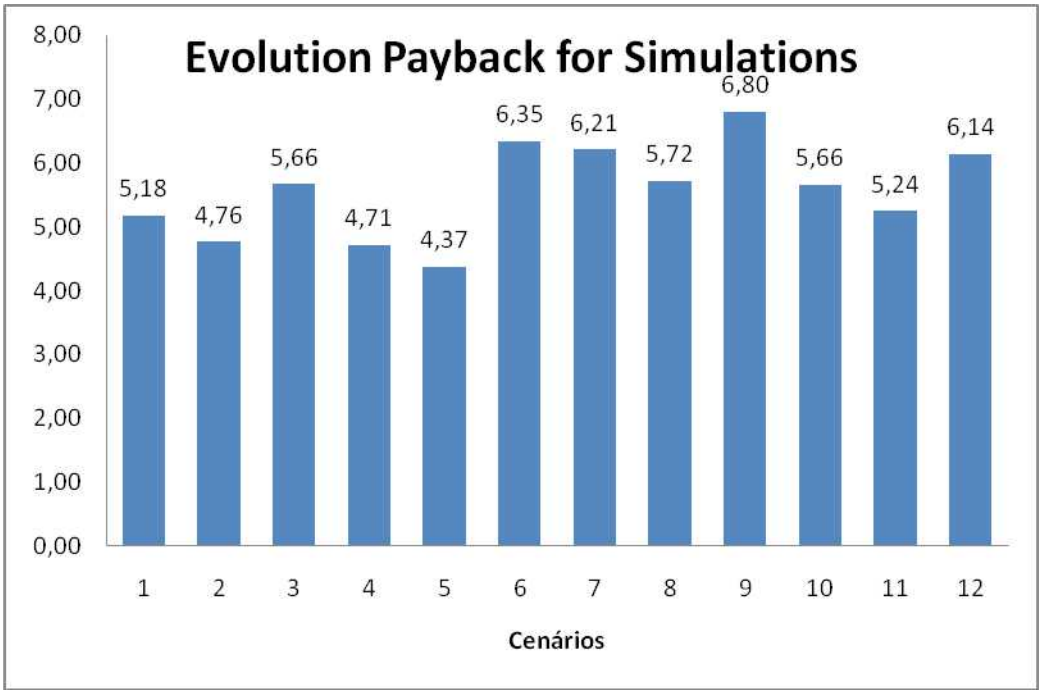

Figure 4.3: Values for the Payback scenarios

6. CONCLUSIONS

Considering the need for ever larger spaces for the disposal of solid waste, and that there is a significant trend that prices for disposal in landfills become high, the results indicate that the thermic treatment by incineration with energy recuperation can be an attractive and competitive option. Since the project involves the disposal of waste in a sustainable way, dealing with the management and manipulation as an acceptable solution for the environment, seems interesting the estimated investment and the establishment of a regional consortium of municipalities.

Is carried out a sensitivity analysis in which is studied the effect of the variation of an input data. The Economic indicators calculated in this analysis were the NPV, IRR and Payback. Analyzing the Table 4.1 it can be seen that only viable were cases where the original parameters are maintained or increased in 20% normative values, or increase of 20% on amounts values by incineration. The cases 1, 2, 4, 5 and 11 proved to be economically viable, as discussed characterized by indicator and NPV.

The IRR must be greater than the rate of pay received by the application of the value of the project budget in another application, for our study we consider the amount invested in savings, the proposed scenarios and analyzing the results presented in Table 4.2 verified profitability in cases 1, 2, 4, 5 and 11, reaffirm these values the data pointed by NPV.

From the point of view of Payback, the project is considered viable when the term found as a result of the calculation is less than the time required to recover the investment, so the scenarios analyzed show a favorable investment Payback.

The study results indicate that despite the initial costs of a WTE plant are relatively high when compared to landfills would be worth if you choose this technology. The problem of MSW in the region of Bauru not ceases to exist. Thus, within the current framework, this study should be considered as an alternative or component of the integrated management of waste.

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