ECONOMIC FEASIBILITY ANALYSIS OF BIODIGESTION CONVERSION OF WASTE COMING FROM A UNIVERSITY RESTAURANT

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Abstract. *The energy crisis and the possibility of a shortage of oil reserves in the coming years, coupled with advancing exploration on the fragile ecosystems, have worried the global community about the irreversibility of drastic reactions that the environment has manifested, such as the greenhouse effect or even global warming. In this scenario, alternative energy sources gain space and biogas has been consolidating as an energy economically viable and environmentally friendly. Researchs on the utilization of organic waste have been developed, in general, using animal manure. Seeking an alternative for disposal of leftover food from a restaurant located on Federal University of Sergipe, we propose the establishment of an anaerobic digester to produce biogas and fertilizer, which can be used by the University in its various actions. To realize this project, a feasibility study of intensive implementation and operation of this equipment has required. Three indicators analyzed: Net Present Value, Internal Rate of Return and payback period. With the result of viability could be ascertained that the proposal has positive indicators, which demonstrates the attractiveness of the venture.*

Keywords*: organic waste, feasibility, biogas.*

1. INTRODUCTION

The increasing population, coupled with human consumption elevation and waste production has brought as a result dramatic increases in rates of pollution and the amount of landfills and dumps. Consequences to the environment are numerous and very serious when waste is disposed of improperly, however most of the wastes are organic in nature, causing accumulation of microorganisms that transmit diseases.

These organic wastes are a good source for the synthesis of biogas and fertilizer through anaerobic decomposition.

The study of digesters is of fundamental importance for technological development, its great application in agro-industrial sectors contributing to the issue of sustainability, and environmentally sound management of wastewater and organic waste, as well as the generation of a renewable and clean energy, because the Biogas obtained from the decomposition of waste can be easily converted to gas for cooking, heating or electricity.

This energy has low cost, the reaction is simple to be conducted. According to Santos (2000), highly purified biogas can reach up to 12,000 kilocalories per cubic meter. Thus, one cubic meter of biogas is equivalent to:

- 0,613 liters de gasoline;
- 0.553 liters of diesel oil;
- 0.454 liters of cooking gas;
- 1.536 kg of firewood;
- 0.790 liters of hydrated alcohol;
- 1.428 kw of electricity.

The objective was to develop a feasibility draft of implanting and operation of a digester for the treatment of waste *coming from* a University Restaurant (RESUN) located at the Federal University of Sergipe. The RESUN offers about 1.500 daily meals.

It is estimated that food wastes in restaurants remain at 15%. Multiplying the amount of food wasted per meal by the percentage of waste that happens in restaurants, you get that are wasted 67.35g of fruit and vegetables per meal in the kitchen industry. For other foods, this value is 30.6 g. Multiplying these 98 g of wasted food at each meal by 1500 meals produced daily by the restaurant of Federal University of Sergipe (UFS), it appears that the kitchen put away 147 kg of food every day.

Converting these values to their equivalent in biogas, 11,25m^3/day of biogas are produced by organic waste from the kitchen.

2. METHODOLOGY

2.1. Marketing aspects

Due to high wastage in Brazil, there is currently a major concern for the problems caused by discharges of liquid effluents and solid wastes. These effluents and waste creates an imbalance in the levels of oxidation of water and imbalance of water population, air pollution, spread of disease-causing microorganisms. Given these facts, there arises the need for treatment and reuse of these wastes. It stands out not only the importance of cleaning up, but also the possibility of generating new technologies from recycling.

The low cost and simplicity of operation refer to the processes of anaerobic treatment of effluents and waste. Anaerobic processes have emerged as the best alternative for the replacement of aerobic systems, in order to reduce the concentration of organic material existing in the effluent. Fact observed by the smallest amount of energy used, if compared to the aerobic processes. In anaerobic processes, there are no artificial aeration equipment, because microorganisms that do not need oxygen to perform their metabolism grows in them and the biogas generated during anaerobic decomposition can be used by industries (FORESTI, 1990).

The resulting biogas from anaerobic conversion features in its basic composition:

TABLE 1 – Typical composition of biogas.

Gas	Symbol	Biogas Concentration (%)
Methane	CH_4	50-80
Carbon Dioxide	CO_2	20-40
Hydrogen	H_2	1-3
Nitrogen	N_2	0,5-3
Sulphur Gas and Others	H_2S, CO, NH_3	1-5

Source: La Farge, 1979 *apud* França *et al*, 2008.

The calorific value of biogas varies depending on the concentration of methane, which in turn depends on the characteristics of the residue used and the operating conditions of the digestion process.

The process of biogas production begins with the effluent being treated, distributing it evenly at the base of the reactor, through the mud layer, transforming the organic matter into biogas. The use of digesters to treat the waste coming from RESUN is a viable option, especially in environmental issues, but success depends on control parameters to identify quickly and safely disturbances in their performance by controlling and monitoring the reaction process.

In step control reaction, the nonexistence of air is one of the optimal conditions for anaerobic bacteria, because oxygen in the air is lethal for anaerobic bacteria, paralyzes the metabolism avoiding the development of microorganisms that synthesize methane gas. The digester must to be built hermetically sealed against the ingress of air, to ensure a complete anaerobiosis inside.

Temperature is an important parameter to be controlled, because anaerobic bacteria are highly sensitive to temperature changes, and the digester also ensures thermal stability during the reaction.

The nutrients from microorganisms are carbon, nitrogen and minerals, if there is not the appropriate balance of carbon compounds and nitrogen will not occur an efficient production of biogas.

The material that will be fermented must have high water content (around 90-95% humidity) in relation to its weight. This control should be carried out rigorously, since excess water is detrimental to fermentation.

2.2 Engineering Aspects

The abundance of biomass sources available in Brazil, the wide range of manufacturing processes used for their recovery and diversity of energy obtained for use by the final brought the country to develop a broad spectrum of activities in the field of biomass. Brazil has favorable climatic conditions to exploit the immense energy from wastewater and organic waste, releasing biogas and fertilizer.

Numerous advantages can be described for the deployment unit for biogas production, but one of the most convenient is the environment. In terms of environmental impact, the environment will have no damage when a digester was implanted, as well as more with the use of industrial wastewater and organic waste for biogas generation, can also allow other industries to save fuel and simultaneously contribute to the control of environmental pollution.

It can be summarized as saying that the anaerobic digestion of wastewater and organic waste is a biochemical process that uses bacterial action to fractionate complex compounds and produce a combustible gas, called biogas. The place to develop these decomposition reactions is the digester. (Nogueira, 1986).

Benicasa et al. (1991) classifies the continuous and batch digesters. Those fed periodically are continuous; the waste is produced in short and regular time intervals. In the batch digester, the effluent to be used are acquired by an interval of time, are loaded at once closed by a convenient period, and organic matter fermented and subsequently discharged.

The installation of digesters agroindustrial areas requires some special care as the field of anaerobic digestion technology, construction and operation of digesters and flow rate sufficient to maintain the digester working. The digesters are sized according to the amount of waste available and are tailored to the needs and different goals such as production of fuel, fertilizer, power and sewage treatment.

According to Ortolani et al. (1991), for the construction of masonry and steel sheet digesters, initially there is need for data of power consumption of the property (motors, lighting, cooking, heating, etc.), type and amount of raw material available on the property. From these data, and knowing the power factor of the effluent (measured in the laboratory or purchased in the literature) are estimated on some initial parameters of the digester, such as height and internal diameters, taking care to keep some fundamental relationships for the proper functioning of digester. From these values, are calculated all the design elements are calculated and subsequently the amounts of masonry materials and plates necessary for the construction of the digester scale.

The calculation of initial parameters for the digester, height and inner diameter can be made according Florentino (2003), with the aid of mathematical optimization techniques. An optimization problem consists of a set of independent variables, also called parameters, the constraints, which are conditions that define the acceptable values for the parameters and objective function that depends on independent variables for a better situation (FLORENTINO, 2003).

Florentino (2003) presents a mathematical tool consisting of a model non-linear programming in order to determine the diameter and height such that it minimizes the volume of this, respecting your limits, which maintain some relationships crucial to the smooth functioning of the digester.

The methodology presented in Ortolani et al. (1991) aided by the techniques proposed in Florentino (2003), allows the development of projects that offer a low cost in the construction of digesters.

2.3 Environmental aspects and legal

Faced with significant challenges regarding the quality, hygiene and safety in agricultural industry, the Ministry of Health created the Order No. 326/97 establishing the improvement of the sanitary control of food and general hygiene requirements and Good Practice Manufacturing for food for human consumption (BRAZIL, 1997).

The treatment of wastewater is one of the most important environmental issues with regard to meeting the legislation and the consequent protection of the environment. While evolving, the lack of resources for investment, the official policies of technological innovation - which seem not to consider the reality of micro and small enterprises in Brazil, among other issues, are obstacles that make the sewage treatment sector in Brazil is still leaves much to be desired (ANDRADE & Sarno, 1990).

The lack of planning in relation to water resources is a major problem that seeks solutions emergency. We need rational administration and a concern to conserve, preserve and reuse the water. Its conservation requires, among other things, the treatment of effluents (Andraus, 1997).

According to Resolution 2005 of August 5, 1993, solid waste is (CONAMA, 2007): “Waste in solid and semi-solid, resulting from community activities: industrial, domestic, hospital, commercial, agricultural, services and sweeping. Included in this definition the mud from water treatment systems, those generated in equipment and facilities for pollution control, and certain liquids whose characteristics make it infeasible its launch in public sewer water bodies, or to require that technical solutions and economically viable, given the best available technology. ".

Thus, the term solid does not necessarily refer to the state that is the material, since liquid substances may be included in this group. It is considered that the solid waste management should understand the stages of separation, packaging, collection, storage, transportation, treatment and final disposal (ANVISA, 2006).

The treatment chosen includes the key advantages discussed during the "Conferência das Nações Unidas sobre Meio Ambiente e Desenvolvimento Humano (CNUMAD)", in Rio de Janeiro in 1992, also known as Rio 92. In chapter 21, of Agenda 21, global action plan on sustainable development, signed by 179 countries, are cited four major program areas related to waste and effluents (MMA 2007 *apud* CANTERI *et al*, 2008): [1] reduction to a minimum, [2] increasing the reuse and recycling to the maximum [3]; promotion of environmentally sound disposal and treatment and [4] extending the range of services dealing with such waste.

2.4. Production Scale

The project feasibility study examines a volume of 147 kg/day of organic waste to be treated through anaerobic digestion procedure. The treatment promotes the production of this volume of 11.25 m^3/day of biogas.

In this feasibility study, the biofertilizer was not part of the recipe, so it was not counted.

2.5. Investment

In this project, feasibility analysis investments are justified for the construction and operation of masonry equipment that enables the processing of wastewater and organic waste into biogas.

The materials included in fixed costs are masonry materials such as sand, block, cement. Among the equipment are listed: pH meter and measurement electronics equipments are responsible for pH control and other important variables in the reaction medium, vital to the process. Computer is needed for the monitoring of data. Transformer and generator are necessary for the transformation of biogas into electricity that will be used in the restaurant, reducing energy consumption and generating revenue. The kit for analysis of biogas is required for quality control of biogas and preventing possible damage to the generator and transformer. For buildings, this investment has fundamental importance because it describes the construction of the equipment.

2.6. Costs and revenues

Fixed Cost and Fixed Costs - Fixed costs and fixed expenses are those that do not depend on the level of company operation thus being equal, these costs are illustrated in Table 2.

Table 2 – Fixed Investment

Specifications	Quantity	Unit (R$)	Total (R$)
Computer	1	1.500,00	1.500,00
Masonry equipments	1	4.000,00	4.000,00
pH meter	1	990,00	990,00
Measuring equipments	1	1.500,00	1.500,00
Tools	1	500,00	500,00
Transformer	1	451,00	451,00
Generator	1	904,00	904,00
Kit for analysis of biogas	1	1500,00	1.500,00
Builtings	1	1.345,00	1.345,00
Total			**12.690,00**

Source: Personal Collection.

Revenues adopted for the analysis of viability are derived from productions of biogas, and are described in Table 3.

Table 3 - Projected operating revenues

Quantity produced	Sale price (R$)	Revenue (R$)
2700,00 kg/year	0,51	1377,00
Fine for non-treatment		2000,00
Total		**3377,00**

Source: Personal Collection

This revenue is generated through processing of waste and sewage into biogas, and this in electricity, that when consumed in the venture creates a new recipe, which makes the proposed venture. The lack of treatment in wastewater and organic waste can result in fines, which according to ADEMA, for midsize restaurants can range from 1500,00 to 6000,00 reais. The value adopted for the feasibility analysis of this project was 2.000,00 dollars

2.7. Investment analysis

The analysis criteria condense all the quantitative information available in a number that, compared with the standard, will accept or reject the investment analysis.

Three basic methods of investment analysis are presented in this project: Payback period: includes the time it takes a company to start making a profit. That is, when the capital spent is zeroed, being offset by profit. Or, in other words, the time the company will take to pay the value of the enterprise. The payback period normally used to indicate the risk of an enterprise. The longer the payback period, the greater the risk. As a method of risk assessment that not includes the time value of money, opportunity cost of potential hazards, and other factors, other methods are sometimes preferred by investors to measure return on capital.

Payback method for analysis of related project:

Notes to the cash flow of investment and calculates the time to recover invested capital from the sum of revenues. The turnaround time was equal to 6.06 years. This indicator had a value in this favorable investment analysis.

Net Present Value: is the sum of present value of projected cash flows for a particular project, which are discounted at a rate that reflects the opportunity cost of applying the money in other funds or alternative projects. The goal of obtaining the NPV of a project is to compare the current values to the returns that the project has the potential to generate.

The net present value for uniforms cash flows can be calculated using Equation 1, where *t* is the amount of time the money was invested in the project, *n* the duration of the project, *i* the cost of capital and FC the cash flows in that period.

$$VPL = \sum_{t=1}^{n} \frac{FC_t}{(1+i)^t} \quad (1)$$

The Method of Net Present Value (NPV) in our feasibility project had a score of 8966,58 reais.

This positive value shows the viability of the project. The positive net present value means that the project gains remunerate investment. The higher the NPV at a given discount rate, more desirable is the project for the company, because the greater is its earning potential. Among all the most used indicators, the Internal Rate of Return (IRR) is that at the first examination, appears to have the minor limitations. This is possibly, because of the independence of information exogenous to the project to its obtaining. The use of IRR attempts to bring together in one single number, the power to decide on a particular project. This number does not depend on market interest rate prevailing in the capital market (hence, the name internal rate of return). The IRR is a number intrinsic to the project and does not depend on any parameter other than the expected cash flows of this project.

IRR is the interest rate that makes the present value of cash inflows equal to the present value of cash outflows of investment. This means that the IRR is the rate that resets the investment. It's such a rate, that if it is used, it makes the profit of its project be null or NPV = 0. The IRR calculation is performed with the help of Equation 2.

$$TIR = J \text{ , then, } \sum {(B_i - C_i)}/{(1+j)^i} = 0 \quad (2)$$

Where J is the discount rate, B_i and C_i are the flows of benefits and costs in the period i. The IRR for the project analysis resulted in 13.51%. The value of the IRR shows that the capital employed in the investment is fully returned, yielding a higher interest rate, the inflation rate used (5%). This indicator confirms the attractiveness of the project over the period considered.

The higher the IRR, the most desirable is the investment. Clearly, under the hypotheses assumed, the lowest possible IRR for the project is cost capital for the company, or its discount rate.

3.CONCLUSION

Quantitative analysis regarding the decision to invest are made from the projections of the project and to indicate the risks of decisions. The criteria considered are those based on cash flow and value of money over time. The exception is the recovery time of the simple capital invested (payback period).

In our project of the feasibility in the treatment of organic waste by digestion process at a University Restaurant was concluded that the proposal has positive indicators, which demonstrates the attractiveness of the venture. We analyzed three indicators (NPV, IRR and payback period). The IRR, for example, a value in excess of inflation considered which reaffirms the attractiveness of the project.

The apportionment of this viability project was not mentioned because the biogas production is an alternative for the treatment of effluents and waste from the restaurant. The biogas which could be generated with the construction of biodigestor in the industry would be incipient for establishment of the energy self-sustainability.

The treatment of wastewater and organic waste by anaerobic digestion process also showed positive indicators for the issues of viability and have important environmental gains.

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