DEVELOPMENT OF A MODEL TO STUDY THE ECONOMIC FEASIBILITY OF USING BIOMASS TO PRODUCE ELETRIC ENERGY IN RURAL PROPERTIES

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Abstract: *This paper presents a study of economic feasibility of deploying biodigester on farms for generating electric energy. The mathematical model proposed uses tools of operational research. The biodigester used is a discontinuous batch-type biodigester, suitable for small farms. In this model are taken into account: the energy produced in the property, the energy market value, the electric power spending, the cost for implementing the biodigester, the time for each cycle of biogas production, the profit from the creation of swine, the number of staff for maintenance, the staff wages, the biodigester useful life, the number of animals and time of swine on the property. As a case of study, the model was applied to a property located in Ibirubá / RS - Brazil, with a 1.188m³ capacity of biogas with biodigester and a flock of 3,000 swine. The results have been obtained through a software application developed in Matlab®, and through them can be seen that this is a viable alternative energy.*

Keywords*: Biomass, Biodigester, Swines, Alternative energy, Economic feasibility*

1. INTRODUCTION

The researches for uses of renewable energy are increasingly drawn the attention aiming to find solutions to the modern world problems. Among these problems, the energy crisis brings concerns both for the fact that many people, especially in rural areas, are not benefited by the available energy resources in Brazil, as verified by the deficiency in the growing service demand. This phenomenon alone is enough to justify the need to seek new sources. Wind energy, solar energy and biomass emerge as promising alternatives capable to promote self-sustainability in small and medium businesses or properties.

Moreover, environmental pollution is a topic of worldwide discussion. Greater than the care about the existing pollution, there is today a concentrated effort in the search for a cleaner and healthier environment eliminating or controlling pollutant sources. As example, we can mention the waste of animals and humans. More specifically, the unpleasant odor caused by swine manure, even in confinement, has worried, especially in areas close to breeding.

2. BIOMASS

This article will show an alternative to minimize the effects of this pollution, through the transformation of waste into biogas as a type of biomass, therefore, as defined by Coldebella (2006), all materials that have the property to decompose by biological effect, that is, by the action of different bacteria, are considered as biomass.

Biomass had great prominence in recent years, primarily by reusing organic material available in nature or produced in specific locations. A concrete example is the use of swine slurry for the production of biogas. There are projections based on surveys conducted in several countries, indicating that the construction of biodigesters can successfully promote electric energy self-sustainability of farms and small residential condominiums in the future.

However, great part of the biomass is difficult to account, due to non-commercial use, it is estimated that, currently, it can represent up to about 14 % of all global primary energy consumption. In some developing countries, this share may increase to 34 %, reaching 60 % in Africa (ANEEL, 2009). The tables (1 and 2) below present data about the consumption of biomass in several countries and the role of biomass energy system.

Table 1- Biomass of consumption
Source: www.aneel.gov.br/aplicacoes/atlas/pdf/05-Biomassa(2).pdf

Country or region	Biomass	Others	Total	%
World	903	5.713	6.643	14
China	206	649	855	24
East Asia	106	316	422	25
South Asia	235	188	423	56
Latin America	73	342	415	18
Africa	205	136	341	60
Developing countries	825	1.632	2.457	34
OCDE countries	81	3.044	3.125	3

Table 2. Role of Biomass in the enregy system
Source:http://www.ana.gov.br/AcoesAdministrativas/RelatorioGestao/Rio10/Riomaisdez/documentos/316-IniciatividadeEnergiaPortugues.wiz

Country	Role of biomass in the energy system
Austria	Modern biomass accounts for 11 % of national energy supply. The forest residues are used for heating, especially in small scale systems.
Brazil	Biomass accounts for about one third of the supply of energy. The main applications are the modern alcohol fuel produced from sugar cane (13-14 billion liters per year) and substantial use of charcoal in the steel industry. The government supports the alcohol. The Pro-alcool is moving toward a program of rationalization to improve efficiency and reduce costs.
Denmark	A program is being designed to use 1.2 million tons of straw and forest residues. Several concepts have been designed to incorporate the burning of biomass in larger scale plants with combined heat and electricity production, heating and digestion of biomass waste.
United States	An electric generation capacity from biomass of about 10,700 MW was installed in 1998, mainly from forest residues. Four billion liters of alcohol are produced annually.
Finland	20 % of its primary energy demand from modern biomass. The pulp and paper industry contributes much through the efficient use of waste for energy production. The government supports the biomass, with the availability of resources, that participation can be duplicated.
Sweden	Modern Biomass accounts for 17 % of national energy demand. The use of waste in the pulp and paper industry and in heating (co-generation of electricity and heat) and the use of wood for ambient heating are dominant. 40 % of national energy supply in 2020 by biomass contribution is projected.
Zimbabwe	Forty million liters of alcohol are produced annually. Biomass meets about 75 percent of national energy demand.

The Administration and Energy Studies Center complements saying that "the biomass has been used in a worldwide growing as energetic input, much more to end uses such as heat energy, but as an important form of electric energy generation, and so also growing as a source of liquid fuels (ethanol).

The contribution of biomass to the reduction of electricity in some countries has always been important. In Brazil, for example, biomass was the first fuel used in thermoelectric plants at the beginning of the century, and in 1995, the generation of electricity from bioenergy resources reached 6.5 TWh, with an installed capacity exceeding 2 GW and representing 30 % of the generation of thermal origin and 2.5 % of total electricity generation. In 2001, it was estimated by the Technical Secretariat Sector Energy Fund that the production of biomass energy was about 3 % of total electricity: 10 TWh (1999), and 4.1 in co-generation in the industrialization of sugarcane, 2.9 in the pulp and paper industry, and about 3 TWh in various unit using agricultural waste. The use of biomass for the generation of electricity in Brazil has increased with more utilization of agricultural and forestry waste. There are some energy generation units in the country using wood waste and several are under implementation. In the U.S., the installed capacity of energy generation from biomass in the early 90s was 8.4 GW, and at the same time the Department of Energy of the U.S. government, planned for 2000 an installed capacity of 12 GW, being able to reach in 2030 about 100 GW (BRAND, 2009).

According to Leandro et. al (2009), the use of biomass can be done so directly as in furnaces and boilers combustion and for feeding livestock, or indirectly through thermochemistry processes (gasification, pyrolysis, liquefaction and transesterification), or biological processes (fermentation and anaerobic digestion)

In this work will be used as reference the anaerobic digestion as the most appropriate in this study. As ANEEL (2009), anaerobic digestion, and pyrolysis, occurs in the absence of air, but in that case, the process is the decomposition of material by the action of bacteria (acidogenic and methanogenic microorganisms).This is a simple process that ocurs naturally in almost all organic compounds. The treatment and energetic utilization of organic waste (animal manure, industrial waste, etc) can be done by anaerobic digestion in biodigesters, where the process is favored by moisture and heat. The heating is caused by the action of bacteria, but in regions or periods of cold, it is possible to need additional heat, as the temperature must be at least 35° C.

The transformation of biomass into biogas using anaerobic digestion is done by biodigesters defined by Winrock (2008) as a closed chamber where organic material is placed for decomposing. There is a very large range of biodigesters that can be classified into continuous and discontinuous.

3. BIODIGESTERS

The discontinuous biodigesters (batch) are suitable for use in small properties, whereas they use as raw material any organic waste (manure of cattle, poultry, swine, sheep, etc.), the aquatic plant *Eichhornia crassipes* (commonly known as Baroness, waterhyacinth, etc.) vinasse, bagasse, organical residues, etc. These organic materials will be anaerobically digested in the biodigester by bacteria, resulting in the production of biogas (60 % to 80 % methane) that will provide power and lighting, but also biofertilizer (17 % to 22 % protein and up to 4 % soluble NPK) (GASPAR, 2003).

By chosing the material used in the biodigester for biogas production, manure of pigs is quite favorable when compared to other animals (birds, cattle, goats), by producing a large amount of daily waste and by the easiness of collection, as that most are created in containment system.

Considering all these advantages, in this study were used batch biodigesters and swine manure for the production of biogas. In swine breeding, the mechanisms (biodigesters) capable to reduce the pollution caused by waste, installed from the last three years in the farms of Brazilian producers, have become key components in projects of clean development mechanisms of swine culture, because eliminate open lagoons where the waste is placed and reduce the activity of the release of methane gas in the atmosphere. In the new system, the biodigester captures methane and produces renewable energy from the biogas. The system reduces the emission of greenhouse gases, reduces odor, reduces water contamination and generates, in a sealed secondary lagoon, the biofertilizer, which can be directly used in farming, bringing big economy to the producers who are less dependent on the purchase of chemist fertilizers. Table 3 shows the growth of swine herds in Brazil in the last ten year.

Table 3: Statement of growth in swine herds in Brazil, during the period 1997 to 2006.
Source: http://www.fundace.org.br/cooperativismo/arquivos_pesquisa_ica_la_2008/056-noronha.pdf

Period	Heads(1.000 u)	Change %
1997	29,637	
1998	30,006	1.25%
1999	30,838	2.77%
2000	31,562	2.35%
2001	31,605	3.30%
2002	31,918	-2.11%
2003	32,304	1.21%
2004	33,085	2.42%
2005	34,063	2.96%
2006	35,173	3.26%

4. MATHEMATICAL MODEL

In this work the analysis of economic feasibility is done using the tools of linear programming. The generic representation of the mathematical model used is shown below.

Maximize or minimize the objective function:

$Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$ (a)

Subject to restrictions:

$a_{12} x_1 + a_{12} x_2 + \ldots + c_{1n} x_n \leq r_1$ (b

$a_{21} x_1 + a_{22} x_2 + \ldots + c_{2n} x_n \leq r_2$ (c)

………

$a_{m1} x_1 + a_{m2} x_2 + \ldots + c_{mn} x_n \leq r_m$ (d)

$x_j \geq 0 \left(j = 1, 2, \ldots, n \right)$ (e)

where:

(a) represents the mathematical function that encodes the goal of the problem and is called objective function (Z). In linear programming this function must be linear.

(b)-(e) represent the mathematical function that encode the major constraints identified.

(e) restriction of non-negativity, which means that the decision variables can take any positive value or zero.

"x_j" are the decision variables that represent the quantities that you will determine to optimize the overall result.

"c_i" are the decision variables that represent the coefficients of gain or cost that each variable is capable of generating.

"r_j"represents the available quantity of each resource.

"a_{ij}" represents the amount of resources that each decision variable consumes.(Moreira, 2003)

Based on the model described above a linear optimization model has been build as it can see below:

$$\begin{aligned} max \quad RL &= RT - CT \\ &= \left(T * P_c * E_p + G_s \right) * x + B_f - C_{man} \end{aligned} \tag{1}$$

submitted to

$$E_p \leq v_d * B_{mo} * E_{cb} * C_{bee} * x \tag{2}$$

$$C_{man} \geq \left(C_f * C_a + C_{ma} \right) * x \tag{3}$$

$$II \geq \left(P_c + I_g + B_{io} \right) * x + G_{er} \tag{4}$$

where:

x – number of swine

L – net income generated by the project

RT – total revenue

CT - total costs

T – total hours analyzed

P_c – the value of electric energy

E_p – electric energy produced

G_s – gain per head of swine

B_f – biofertilizer

II –initial investiment

C_{man} – cost of maintaining equipment

G_e – expenditure of energy in swines

N_f – number of staff

S_f – staff wages

m – number of months of the period

D – depreciation

P – paint the installations of the swines

L – exchange of canvases

M_t –exchange of motor generator

V_d – volume of waste per head per day

$B_{mo} = 0.75$ → organic matter degrability

$E_{cb} = 0.85$ → efficiency of conversion in biodigester

$C_{bee} = 0.25$ → conversion of biogas into electricity (Otto cycle)

C_f– cost of the employee per number of heads of swines
C_a – cost of food per swine's head
C_{ma} – cost of installation maintaining per head of swines
P_c – price per head of swines
I_g – the cost of installing meters for number of swine per meter
B_{io} – cost of cubic meter of biodigester by the number of swine heads
G_{er} – cost of electric generator

Since the maximized RL, it can make a profitability economic and financial analysis of the project. The economic analysis will answer the FE, which is the contribution of the project for monetary availability.

$$FE = RL+D \tag{5}$$

FE is the economic flow generated by the project, RL the liquid income, and D the depreciation of equipment.

For the profitability analysis is used a minimum rate of attractiveness - also called the opportunity cost or discount rate - that is paid by current financial market investment in current (savings, investment funds, among others). This rate is used to represent the cash flows into present values. The analysis of profitability will be made taking into account three indicators:

a) The Present Value (NPV), which is current net return generated by the project, which allows to analyze the economic feasibility of the project at long term.

$$NPV = -II + \sum_{j=1}^{n} \frac{FEj}{(1+r)^n} \tag{6}$$

FEj represents the economic flow of the project for period; *n* the number of times that represents the horizon of the project, *j* one period; and *r* the interest rate charged per period.

b) The Internal Rate of Return (IRR), which is the interest rate that the NPV reset, shows the maximum rate of interest that a project supported; the higher the IRR, more desirable is the investment.

$$\sum_{j=1}^{n} \frac{FE_j}{(1+\alpha)^n} = 0 \tag{7}$$

FEj represents the economic floe of Project for period, *n* the number of times that represents the horizon of the project, *j* a period and α the internal rate of return.(Lapponi, 2000)

5. CASE STUDY AND RESULTS

For the validation of the model to be studied, it was chosen a rural property in the municipality of Ibirubá-RS-Brazil. Data collected in this property will be used to generate the scenarios below.

Three scenarios will be shown, taking into account the minimum rate of attractiveness; however a much greater range of scenarios is possible. The following data are used in all scenarios:

-U$1.00 is equivalent a R$ 2.07 (quotation in 18/05/2009)
-Kwh/Utility: U$ 0.12
-Lifetime of the project: 5 years

Table 4. Scenario 1: minimum rate of attractiveness = 0 %

Scenario 1	
Initial Investment	U$ 96,618,36
Total revenue	U$ 295,488.69
Net revenues	U$ 235,778.55
Total costs	U$ 59,710.14
Economic flow	U$ 58,341.35
Net Present Value	U$ 58,341.35
Internal rate of return	9.91%
Period Recovery of Capital	3 years

Table 5. Scenario 2: minimum rate of attractiveness = 6 %

Scenario 2	
Initial Investment	U$ 96,618,36
Total revenue	U$ 295,488.69
Net revenues	U$ 235,778.55
Total costs	U$ 59,710.14
Economic flow	U$ 58,341.35
Net Present Value	U$ 34,417.73
Internal rate of return	12.66 %
Period Recovery of Capital	3 years

Table 6. Scenario 3: minimum rate of attractiveness = 12 %

Scenario 3	
Initial Investment	U$ 96,618,36
Total revenue	U$ 295,488.69
Net revenues	U$ 235,778.55
Total costs	U$ 59,710.14
Economic flow	U$ 58,341.35
Net Present Value	U$ 15,926.13
Internal rate of return	15.47 %
Period Recovery of Capital	3 years

6. CONCLUSION

The biogas would just be a product generated by a swine waste treatment process, which would allow the farmers to become self-sufficient in electric energy depending on their consumption for pay the capital invested in a system of waste treatment.

Another advantage in the use of biogas is the fact that methane is a gas that contributes to the greenhouse effect more intensely that carbon dioxide and its burning for energy generation contributes to the reduction of its effect as such.

The three scenarios show the return on initial capital invested, that is, the capital is recovered independently of the rate of attractiveness shown in each scenario. This shows that the production of electric energy through the use of biodigestor in rural properties is valid and promising. Worth emphasizing that the mathematical model described in this work is in the process of testing and improvement, however already showing good results as those described in the scenarios above, but there are details to be improved and information to be added to better performance and flexibility.

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