USE OF SWINE WASTE IN THE PRODUCTION OF ELECTRIC ENERGY FROM THE EFFICIENT USE OF BIODIGESTORS: THE BRAZILIAN CASE

Anderson Catapan

ABSTRACT

Objective: to calculate the minimum number of animals that a rural pig farm needs to raise so that the implementation of biodigesters to generate clean energy in the context of Brazil is financially viable.

Theoretical framework: a more efficient productive farm tends to include environmentally sustainable actions, since pig farming is considered a relevant activity of environmental concerns due to the amount of manure produced, especially in an intensive system. It is in this context that several current studies have been debating the environmentally correct reuse of pig manure.

Method: using interviews and exploratory searches, data were collected that projected the project's cash flow. From this, the number of animals needed for the net present value of the project to be zeroed was calculated. Also, the probabilistic scenario was designed using the Monte Carlo Simulation.

Results and conclusion: for the deterministic scenario, it was calculated that 736 animals are needed for zero/null NPV and for a probabilistic scenario context with p(NPV<0) = p(IRR<TMA) = 0.2, it is necessary that the rural property has at least 840 animals.

Research implications: the academic and social contribution of this work is that it can help small swine producers in their decision-making for the implementation of biodigesters.

Originality/value: considering rural activities as strong polluters and the large increase in electricity tariffs seen in recent years, mainly due to severe droughts and the COVID-19 pandemic, the reuse of waste becomes increasingly important and relevant for clean and distributed energy generation.

Keywords: Manure, Pigs, Clean Energy, Biodigesters, Investment Analysis.
Resultados e conclusão: para o cenário determinístico, foi calculado que são necessários 736 animais para o VPL zero/nulo e para um contexto de cenário probabilístico com \( p(\text{VPL}<0) = p(\text{TIR}<\text{TMA}) = 0.2 \), é necessário que a propriedade rural tenha pelo menos 840 animais.

Implicações da pesquisa: a contribuição acadêmica e social deste trabalho é que ele pode auxiliar pequenos produtores de suínos na sua tomada de decisão para implementação de biodigestores.

Originalidade/valor: considerando as atividades rurais como fortes poluidoras e o grande aumento da tarifa de energia elétrica visto nos últimos anos, principalmente devido a grandes secas e à pandemia de COVID-19, cada vez mais se torna importante e relevante a reutilização de dejetos para geração de energia limpa e distribuída.

Palavras-chave: Dejetos, Suínos, Energia Limpa, Biodigestores, Análise de Investimento.

The activity of pig breeding in farms is relevant to the food industry production chain, currently counting in the context of Brazil with an approximate herd of 49.3 million head (IBGE, 2022).

When pigs are reared, the amount of waste generated can always vary. This depends, among other variables that may influence, on the number and type of animals, whether they are piglets or females, whether males are of growing age or of terminal age, or whether they are male reproducers (Catapan et al., 2013). Also, other variables that can also influence the amount of waste generated by a farm are the physical facilities, as well as the equipment, besides the forms of cleaning that are carried out in the farms (Catapan et al., 2013).

A more efficient production farm tends to include environmentally sustainable actions, as pig farming is considered a relevant environmental concern activity due to the amount of manure produced, especially in intensive systems (Tonetto et al., 2021). It is in this context that several current studies have been discussing the environmentally correct reuse of pig waste (Sousa et al., 2020; Ramires et. al., 2020; Fernandes e Silva, 2020, Santos, 2022; Bender, 2022).

From this perspective, the objective of this work involves calculating the minimum number of animals that a rural property of pigs needs to create so that it is financially viable to implant biodigesters to generate clean energy in the context of Brazil.

The research started with an exploratory theoretical and data survey stage, followed by a stage of financial projections and calculations. The initial step of the exploratory stage
involves obtaining the value of kilowatt/hour of energy in Brazil, given that it will be obtained from examining the dealers' electricity bills. Also, we sought to find profitability of low-risk applications, search which was carried out on the sites of commercial banks, for calculation of the TMA, and on the market averages obtained, will be added a premium for risk, reaching the effective TMA of the project.

The next step in the exploratory stage of this research involved finding farms that use biodigesters in Brazil so that interviews could be carried out to search for the data. The intention was to carry out the interviews with employees, if possible, owners, which were recorded and transcribed at a second moment.

In these interviews, they sought to obtain the salary of employees (which was also verified by means of research in unions), wage charges (research was also carried out in government agencies), besides monthly expenses with the biodigester, such as maintenance, depreciation, cleaning materials and expenses in general, information which was also confronted with resellers of biodigesters.

With all the data obtained, the cash flows were projected and then the quantity of animals needed to obtain a NPV equal to zero was calculated. Next, the variabilities of input parameters (maintenance of the biodigester, cleaning materials and expenses in general) were imputed for calculating the probabilistic scenario, by means of the Monte Carlo simulation, which was carried out with the "Crystal Ball" software.

It was chosen to use Monte Carlo Simulation to the detriment of other traditional regression techniques, since several other works that analyzed variability and probabilistic scenarios, in the context of investment analysis, also used this technique (Maitra, Gaikwad and Short, 2004; Arnold and Yildiz, 2015; Batan, Graff and Bradley, 2016; Uwineza, Kim and Kim, 2021; Youssefi, Celik and Azimli, 2022).

The last stage of the research involved calculating the number of pigs necessary to obtain NPV, that is, zero financial viability, considering for this two scenarios: in the first where the calculation parameters are fixed and the second where they are variable, a scenario in which a minimum number of animals was suggested so that the possible investor would have little probability of losing his money with this project, (p < 0.2), with confidence level p value of 95%.

It was chosen to use p < 0.2 also based on previous work, which analyzed investments using Monte Carlo Simulation (Catapan et al., 2013; Ogata et al., 2014; Greca et al., 2014; Catapan et al., 2016; Suchla and Catapan, 2021).

3 RESULTS AND DISCUSSIONS

The first step in any investment analysis that considers the value of money over time is to design/calculate the Minimum Rate of Attractiveness (MBA) of the biodigester efficient use project. This is a subjective measure, since it can change according to the perception of investors, but for calculation purposes, this work opted to measure it considering the average profitability of low-risk financial products, withdrawing income tax, and adding to the average price a risk premium. In this context, Table 1 presents the calculation memory for TMA.
Table 1 - Rates of Low-Risk Brazilian Financial Products

Source: Research Data (2023).

The simple annual average of the yields obtained is 9.94%. Calculating the compound monthly average (considering compound interest), they have 0.79% per month. Considering the frequent variation in profitability of financial applications, it is noted that the data presented here were collected in October/2022. Taking the view that, in the context of investment projects, the higher a risk of a given project, the higher the risk premium attached to TMA, and assuming that the returns presented are low risk, an EBA higher than this profitability should be accepted.

In this context, considering that a hypothetical option for an investor to invest its capital in a pig waste farm would bring a risk higher than the risk of investing its capital in the aforementioned financial products, it was arbitrarily considered a risk premium of 0.31% per month, arriving at a monthly TMA of 1.1%.

Designed the TMA of the efficient use of biodigesters project, the next step involves designing the initial investments as well as the cash outflows, as the inputs will be calculated later. Thus, Table 2 brings the necessary investments, as well as the projected outflows for the cash flows.

Table 2 - Monthly Project Investments and Outflows

Source: Research Data (2023).

The values presented in Table 2 were measured based on in-depth interviews with farm owners, as well as surveys with biodigester resellers.

The next step in the cash flow projection of this project is to calculate the amount of tons of Biogas per year from the anaerobic decomposition process of pig waste. Thus, it is assumed that the average volume of manure that each pig produces daily is 2.25 kg, and the volume of biogas that is generated per kilogram of pig manure is 0.062 m³ (Barrera, 1993; Catapan, Carvalho, Catapan, 2011; Catapan, Catapan, Catapan, 2011; Catapan et al., 2013).

In order to be able to measure the quantity of methane that will be produced per year, it is necessary to calculate the total of Biogas produced, besides its corresponding in relation to the percentage of methane that is to be found in the said Biogas, which according to Carvalho and Nolasco (2006) is on average 66% for pig waste.

Lastly, the amount of methane generated must be multiplied by the conversion rate to kilowatt-hour, which according to Prati (2010) is 5.5 kWh per m³. Then, the product of this
result is realized by the value of the kilowatt/hour that is taxed by the company that sells energy (electricity concessionaire) to obtain the projected monthly revenue.

The justification for using the amount charged by the energy company is that, in this particular project, the energy generated will be used for use on the farm itself, to the detriment of the possibility of marketing the energy. It should be noted that in cases the owner of the farm or the investor chooses to market the energy, must use the value of the kilowatt/hour of the sale of electricity to the concessionaire.

In this context, Table 3 presents the calculation memory used to obtain the projected monthly revenue for a zero Net Present Value, i.e. it is the scenario where no money is earned and no money is lost. It is chosen to simulate this scenario in order to understand what the minimum quantity of animals present in a farm is, to make financially viable the implementation of a biodigester.

<table>
<thead>
<tr>
<th>Returns TRUE on success or FALSE on failure.</th>
<th>Values</th>
<th>Variation For Monte Carlo Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (kilogram) of waste per day</td>
<td>2.25</td>
<td>10%</td>
</tr>
<tr>
<td>Number of animals</td>
<td>736</td>
<td>-</td>
</tr>
<tr>
<td>Total volume (kilogram) of waste per day</td>
<td>1 656.00</td>
<td>-</td>
</tr>
<tr>
<td>Total volume (kilogram) of waste per month</td>
<td>49 680.00</td>
<td>-</td>
</tr>
<tr>
<td>Conversion rate of pigs</td>
<td>0.063</td>
<td>10%</td>
</tr>
<tr>
<td>Volume (m³)</td>
<td>3 129.84</td>
<td>-</td>
</tr>
<tr>
<td>Conversion rate of methane to pigs</td>
<td>60%</td>
<td>10%</td>
</tr>
<tr>
<td>Methane volume (m³)</td>
<td>1 877.90</td>
<td>-</td>
</tr>
<tr>
<td>Kilowatt/hour conversion rate</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Total kilowatt/hour generated</td>
<td>10,328.47</td>
<td>-</td>
</tr>
<tr>
<td>Kilowatt/hour value</td>
<td>R$0.86</td>
<td>-</td>
</tr>
<tr>
<td>Projected monthly revenue</td>
<td>R$8,882.49</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3 - Revenue Calculation Required For Null VPL
Source: Research Data (2023).

The value of the KWh of R$ 0.86 was based on the CPFL Paulista, for commercial tariff. The use of this concessionaire is justified because it is the most populous Brazilian state, and where the majority of companies in the country are concentrated.

The calculation of the number of animals was done with the help of the Microsoft Excel tool "Scenario - Achieve Goal", which makes an analysis similar to a linear interpolation. For this, considering the initial investment and the cash outflows in Table 3, the NAV was set to zero and the parameter for the number of animals was varied, leaving all other data as constant. Null/zero VPL was then obtained with **736 pigs**.

The next step is the cash flow projection, generated from this quantity of animals, which is projected in Table 4, in summary form, showing the moment 0 (initial investment), and the subsequent months, disregarding inflation and price increase of the value of KWh and monthly costs and expenses.
It should be noted that 40% of the total initial investments and a project time of 60 months (5 years) were used as residual value. It is justified to use this high residual value rate because the higher value (generator) does not tend to become as obsolete or useless after the 5-year project time. The depreciation rate was not used because, in line with the residual value, the assumption of a depreciation of 60% of the initial investments at the end of the 5 years.

The next step shows the probabilistic scenario, considering the variations in the fixed input parameters, and the result of this scenario, run through Monte Carlo Simulation is shown in Figure 1.

![Figure 1 - Monte Carlo Simulation - VPL](image)

This computer simulation was carried out in the Crystal Ball software with 5,000 interactions, normal distribution for the variables and in the graph was presented the certainty range of 46.00%. In this context, the result shows a VPL with certainty interval is - R$33,405.52 to R$33,405.52, that is, with 46% certainty the VPL will vary between these values. Assuming that the probability of losing money, considering the variable assumptions is high in this case, a new probabilistic scenario was analyzed, admitting a maximum of 20% chance of losing money, results which are set out in Figure 2.
Figure 2 - Monte Carlo Simulation - VPL with 20% chance of losing money

In this new simulation we admitted 20% of chances of losing money, that is, \( p(\text{VPL}<0) = p(\text{TIR}<\text{TMA}) = 0.2 \). For this case, the simulation indicated the need for the rural farm to have at least **840 animals** in the Brazilian context.

4 FINAL CONSIDERATIONS

The general objective of the present study was "the objective of this work involves calculating the minimum number of animals that a rural property of pigs needs to create in order to make it financially viable to implant biodigesters to generate clean energy in the context of Brazil". It was considered that the general objective was met, since with the number of the deterministic scenario of 736 animals needed for the zero/zero VPL in Brazil, it can be concluded that it is possible and feasible to generate clean energy in small sized rural properties.

Considering a probabilistic scenario context with \( p(\text{VPL}<0) = p(\text{TIR}<\text{TMA}) = 0.2 \), it is necessary that the farm has at least 840 animals, fulfilling the premise of a maximum risk of 20% of chances of losing money with the project, that is, of negative VPL.

This work was limited to calculating and understanding the reality of the Brazilian context for designing the use of biodigestors. In this sense, and considering this limitation, it is suggested that in future works the realities of other countries be studied, since impacts such as energy price and labor value, as well as initial costs, can have a great impact on the results projected and obtained here.

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