THE FINANCIAL VIABILITY FOR CLEAN ENERGY GENERATION FROM SWINE WASTE: A COMPARATIVE STUDY BETWEEN BRAZIL AND ECUADOR VIA A MONTE CARLO SIMULATION METHOD[1]

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Abstract

The paper is written via a comparison of costs associated with the production of clean energy from swine waste in the Latin American countries of Brazil and Ecuador. Objective: The objective of the study is to study the financial viability of the use of a bio-digester in the two countries to allow for a comparison of the associated costs via cash flow analysis. Results: The results show that in order to meet financial viability allowing for a maximum 20% risk of investors losing money,

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that there is a need for bigger farms in Ecuador than in Brazil. Conclusion: The paper shows that by calculating the financial viability, a minimum number of swines are needed in each country. This is due to differing implementation costs in the two countries. Sustainability and conversation are only two of the positive results of generating energy in this way.

Keywords: clean energy; Monte Carlo Simulation; costs; viability

VIABILIDADE FINANCEIRA PARA GERAÇÃO DE ENERGIA LIMPA A PARTIR DE DEJETOS DE SUÍNOS: UM ESTUDO COMPARATIVO ENTRE BRASIL E EQUADOR COM O USO DA SIMULAÇÃO DE MONTE CARLO[6]

Resumo

O documento foi escrito por meio de uma comparação dos custos associados à produção de energia limpa a partir de dejetos de suínos nos países latino-americanos do Brasil e do Equador. Objetivo: O objetivo do estudo é estudar a viabilidade financeira do uso de um bio-digestor nos dois países para permitir uma comparação entre os custos associados através de análise de fluxo de caixa. Resultados: Os resultados demonstram que, a fim de satisfazer a viabilidade financeira, que permita um risco máximo de 20% de investidores perder dinheiro, que existe uma necessidade para explorações de maiores dimensões do que no Equador no Brasil. Conclusão: O trabalho mostra que pelo cálculo da viabilidade financeira, são necessários um número mínimo de suínos em cada país. Isto é devido aos diferentes custos de implementação dos dois países.

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Sustentabilidade e conversa são apenas dois dos resultados positivos de geração de energia dessa forma.

Palavras-chave: energia limpa; simulação de Monte Carlo; custos; viabilidade

Introduction

In the 21st century, we are currently suffering from an increasing shortage of petroleum worldwide, as well as a growing concern for man-induced climate change caused via the burning of fossil fuels. Consequently, we have seen a growing number of research and feasibility studies aimed at the adoption of “clean” energy production, which is also interchangeably known as alternative or renewable energy (KORHONEN et.al., 2004; CATAPAN et. al., 2013b). From this perspective, we are led to biomass, an organic material found in animal or vegetable organisms, which can be retrieved through forest, agricultural, livestock and municipal waste, and among its uses, can prove useful in the fertilization of soils for agriculture or for the production of primary energy (GEBLER; PALHARES, 2007).

From biomass, we are then lead logically to biogas, which is a product that results from the anaerobic decomposition of organic matter, occurring through the actions of certain bacteria (GEBLER; PALHARES, 2007). Through bio-digesters, which the play the role of converting biogas into energy, we are therefore able to see realization of how renewable energy can be generated. The big issues however, for the deployment of these bio-digesters are the initial costs of acquisition and then the deployment of the equipment needed for energy generation, i.e. the financial viability.

As such, the research question of this article is to determine: What is the equilibrium point, in which the number of livestock needed in order to make the implementation of a bio-digester for electricity generation via the use of swine waste in Brazil and Ecuador becomes financially viable?

In this regard, the objective of the research is to focus on the calculation (via the use of investment analysis techniques), of an equilibrium point in terms of the number of livestock needed, in order to make the implementation of bio-digesters for electricity production through the use of swine waste financially viable in Brazil and Ecuador.

The research is justified for both countries, as global agricultural activity has the potential to be a pollutant when the waste is simply disposed of in the soil or earth. As a result, it is vital that there be a change in the way in which we manage or handle environmental control, since, if the waste is simply thrown on crops or soil, there lies a possibility in the long term of serious environmental risks and a greater problem for any future local government in how to deal with waste (DIAZ; DIDONET, 2009).

Environmental awareness, in relation to waste storage and treatment must accompany the technological jumps, which have been developed alongside globalization and are present in production methods. This is done by taking into account the complexity of the problems that depositing waste in the soil causes, such as the environmental impacts on soil, water and air (KUNZ; HIGARASHI; OLIVEIRA, 2005) e (CATAPAN; OAK; CATAPAN, 2011).

However, in addition to avoiding this environmental impact, the taking advantage of the possibility of using waste for energy generation, with financial viability, is a way for farms of aggregating more value to their activities in both countries, oiling a future business relationship in relation to changes in innovative practices (DIAZ; DIDONET, 2012) and in generating a new market orientation, so that new companies can add value to their activities (DIDONET et al., 2012).

The practical contribution of this research is focused on assisting farmers and agricultural production workers in being able to make decisions as to whether to consider the possibility of implementing sustainable energy generators. The article is here forth split into the following sections: methodology, analysis and discussion of the results and finally conclusions.

Methodology

The research begins with a theoretical stage, which comprises of the extraction of technical information about swine waste as well as information about the composition of biogas, referenced in (CATAPAN et al., 2013) with methods and techniques of social research (GIL, 2010). The next step is the collection of data in order to be able to carry out the financial viability calculations. Figure 1 illustrates the variables needed in order to perform this calculation as well as the proposal to collect such information.

Figure 1: Research Variables and Data Collection Method

Variable	Data Collection Method
KWh Value	Investigations into electricity and utility bills
Rates of low risk applications	Investigations into banks and financial institutions
Average Salary	Interviews on farms
Salary Costs	Interviews on farms and investigations into government agencies
Bio-digester maintenance	Interviews on farms and product distributors
Depreciation of bio-digester	Interviews on farms and product distributors
Bio-digester cleaning materials	Interviews on farms and product distributors
Overheads	Interviews on farms and product distributors

Source: The Authors (2014)

Visits were made to pig farms in Brazil and Ecuador in order to learn about the bio-digesters and their monthly expenses (maintenance, cleaning, operation etc.). The monthly maintenance costs, the operating and cleaning of the bio-digesters were identified and collected based on the responses from the interviews with the owners of the farms and also via an examination of the expense control spreadsheets compiled by the owners. For the initial set-up costs, research was carried out for the acquisition of the bio-digester in both countries.

In order to work out the issues to do with cash flow, and with the aim of further analysis of the financial viability; the amount of biogas created from the waste of each animal will be calculated and subsequently converted into kWh. Based on the amount of kWh, the value of the cash inflows generated by the biogas will then be calculated, and vary, depending on country, given that each operator charges different prices per kWh.

With this information, the cash flow designs for the two countries will be developed as well as the Minimum Rate of Attractiveness for each country. From this the number of animals needed will be found, when taking into account the null Net Present Value (NPV), and after considering that all input parameters are fixed. Secondly, the *Monte Carlo Simulation* will be used with *Crystal Ball* software (used to operate and run this simulation) given that some entry premises represent values that can become variables (maintenance, cleaning, amount of waste generated daily, amount of methane in biogas).

The Monte Carlo simulation is a statistical method that consists of generating *n* random samples that are then tested in a statistical model as a probability distribution for a given project (FERNANDES, 2005). Thus, each sample corresponds in fact to a given iteration for the model (FERNANDES, 2005). Based on these iterations, the model error can be calculated by Formula 1 (FERNANDES, 2005):

[1]

In which,
= Total error of the model;
= Standard deviation of the random variable;
= Number of iterations.

Therefore, based on Formula 1, it can be seen that the higher the number of iterations of the model, the smaller the error.

Finally, a new minimum number of animals needed in order to achieve financially viability will be measured, taking into account such premises suggested in variable form, so that there will be a minimum number of animals for which a potential investor has little chance of losing money on with this project ($p < 0.2$).

Analysis and Discussion of Results

In order to calculate the financial viability, one first, must calculate the amount of metric tons of biogas per year, to be able to do this, the first step is to take into account the amount of manure generated daily per swine (2.25 kg per day) and the volume of biogas generated per kg of waste (0.062 m3 of biogas) (BARRERA, 1993) e (CATAPAN et al., 2013a.).

Following on, in order to calculate the amount of methane produced from the biogas, the percentage of methane existing in the biogas needs to be considered (66% for swines) (NOLASCO; CARVALHO, 2006). Then, you need to multiply the amount of methane generated by the conversion rate for kWh, which is 5.5 KWh per m^3 (PRATI, 2010). Finally, the amount charged by the energy supplier per kWh to reach monthly revenue levels is taken into account. As shown by the initial premises for calculating the NPV, an analysis is now made for each of the two countries in the study.

Brazil

Table 1 shows the investments and outflows considered for the cash flows in the Brazilian context; these were based on the data collected during the research stage.

Table 1: Investment and Outflows of Detailed Cash Flows (Brazil)

Investments	Value	Outflows	Value	Variation (Crystal Ball)
Generator	R$ 95.000,00	Salaries/ Expenses	R$ 2.700,00	-
Pond	R$ 4.000,00	Maintenance	R$ 200,00	5%
Bio-digester	R$ 64.800,00	Cleaning	R$ 50,00	5%
Infrastructure	R$ 15.000,00	Expenses	R$ 50,00	5%
Total	R$ 178.800,00	Total	R$ 3.000,00	

Source: The Authors (2014).

In Table 1, the 5% variation in relation to the Crystal Ball for spending on maintenance, cleaning and general expenses was based on interviews with the owners as well as previous studies. Therefore, this percentage means that, on average, these values can fluctuate either positively or negatively by 5%. Salaries and social charges are naturally fixed, since they cannot be varied during the months of the project and the monetary values are expressed in the Brazilian currency, the Real (R$).

Table 2 shows the calculation measurement sheet of monthly revenue generated from biogas energy production, considering a null net present value (NPV), in other words, the total inflow equals the total outflow of the cash flow.

Table 2: Calculation sheet For Financial Viability (Brazil)

Description	Values	Variation (Crystal Ball)
Waste Volume per day (kg)	2.25	10%
Number of Animals	1040	-
Total Volume of waste per day (kg)	2340.00	-
Total Volume of waste per month (kg)	70,200.00	-
Conversion Rate	0.063	10%
Volume (m3)	4423.00	-
Conversion Rate	60%	10%
Methane Volume (m3)	2654.00	-
Conversion Rate KWh	5.5	-
Total KWh Generated	14,595.00	-
KWh Value (Brazil)	R$ 0.39	-
Monthly Revenue Generated	R$ 5639.78	-

Source: The Authors (2014)

The value of KWh was measured based on the value provided by *Companhia Paranaense de Energia* (Copel), in reference to the month of March, 2014. The calculation of the number of animals was performed using *Scenario - Goal Seek Excel*, by considering the parameter variation in the number of animals and setting the NPV to zero. Thus, it was found that the null NPV is approximately 1040 animals. For this calculation, the Minimum Rate Attractiveness (MRA) was set at 8% per year. This value was calculated based on returns of investment funds available, plus a risk premium.

The column variation illustrates the parameters that were considered as variables for the purposes of the Monte Carlo simulation. The definition for the variable parameters was also taken from interviews as well as previous work. Based on this revenue generated, the project cash flow is illustrated in Table 3.

Table 3: Cash Flow (Brazil)

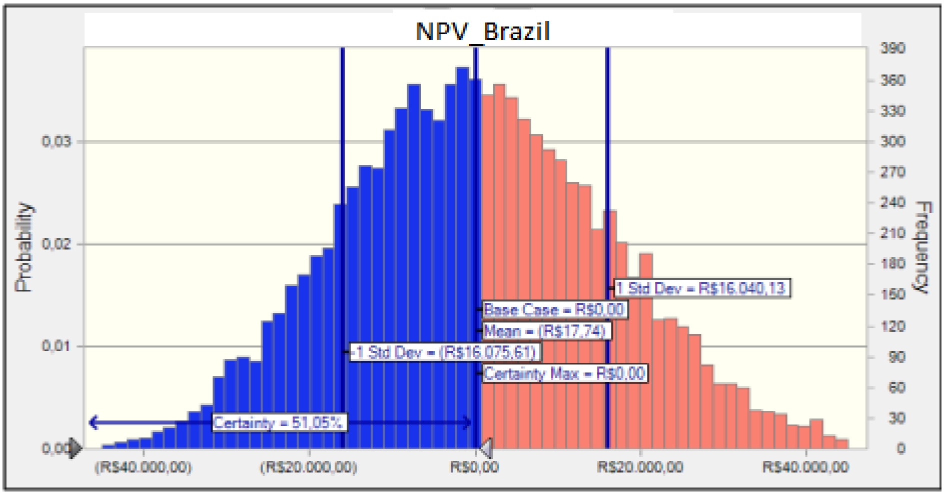
Month	0	1	2	…	60
Inflows	-	R$ 5639.78	R$ 5639.78	R$ 5639.78	R$ 78,839.78
Outflows	R$ 178,800.00	R$ 3000.00	R$ 3000.00	R$ 3000.00	R$ 3000.00
Cash Flow	-R$ 178,800.00	R$ 2639.78	R$ 2639.78	R$ 2639.78	R$ 73,839.78

Source: The Authors (2014).

The cash flow covers a period of 5 years (or 60 months), as, in the interviews, it was stated that on average, owners replace the bio-digester every 5 years. In the last flow (60th month), 40% of the investment value is considered as a residual value, given as this period saw the deployment of a new set of bio-digester equipment which is seen as a new investment project.

From this cash flow, the NPV obtained is null, and the calculated IRR is approximately equal to the MRA presented, i.e. there exists from the specified number of animals, financial feasibility for the implementation of the bio-digester, disregarding the variation of parameters. The premises of variation of parameters for Monte Carlo simulation will now be considered.

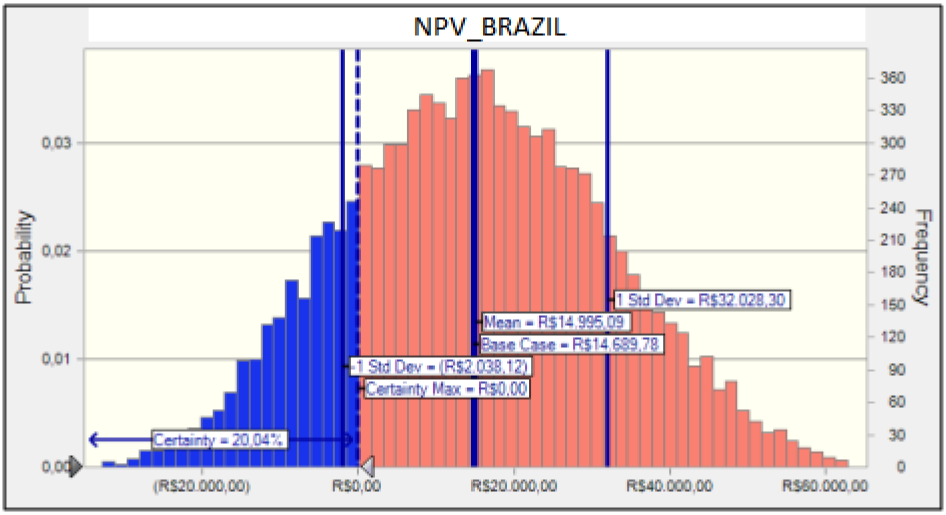
Figure 1: Monte Carlo Simulation (Brazil)



The Monte Carlo simulation was performed with 10,000 interactions and with a 95% confidence interval. The NPV for the swine waste in Brazil resulted in an average value of R$ 17.74, with a minimum NPV of R$ 47,325.49 and a maximum of R$ 52,105.94 (with a standard deviation of R$ 16,057.87). The Monte Carlo Simulation also indicates that the probability of NPV is less than zero, or that the IRR is less than the MRA at 0.5105, therefore it can be shown that p(NPV <0) = p(IRR<MRA) = 0.5105, indicating a considerably high risk of not recovering the invested capital, if the number of animals is kept at approximately 1040 animals. This risk is considered, to be generally too high to attract investors.

Assuming that the investor is able to take a maximum risk of losing money on the project at 20%, then p(NPV <0) = p(IRR <MRA) should be at most equal to 0.20. Carrying out once again the Monte Carlo Simulation within these parameters, the minimum number of pigs needed to satisfy this premise is 1095 animals. Figure 2 shows the graph of this simulation.

Figure 2: Monte Carlo Simulation for Risk at 20% (Brazil)



Within this scenario, the probability of the NPV being obtained greater than zero at 0.7996, with a 95% level of confidence, will be between R$ 33,426.08 and R$ 68,107.44 (with a standard deviation of R$ 17,033.21). Thus, the chance of losing the investor´s money is at 20.04%, whilst this new scenario provides figures of p(NPV <0) = p(IRR <MRA) = 0.2004. This is therefore considered to be the minimum number of animals needed in order to achieve financial viability in Brazil. The following section analyses this context in Ecuador.

Ecuador

Table 4 presents the investments and outflows considered for the cash flows in the Ecuadorian context, which are taken based on the exploratory stage of data collection of the study.

Table 4: Investments and Expenses Detailed Cash Flows (Ecuador)

Investments	Value	Expenses	Valor	Variation (Crystal Ball)
Generator	US$ 11.500,00	Salaries and expenses	US$ 560,00	-
Pond	US$ 1.500,00	Maintenance	US$ 150,00	5%
Bio-digester	US$ 6.500,00	Cleaning	US$ 80,00	5%
Infrastructure	US$ 2.500,00	Costs	US$ 70,00	5%
Total	US$ 1.100.000,00	Total	US$ 860,00	

Source: The Authors (2014).

In Table 4, the salaries and expenses total US$ 560.00, comprises of US$ 500.00 monthly in salaries, and 12% tax on the payroll. The 5% variation on the Crystal Ball, similarly to the case in Brazil, allows for the amount spent on maintenance, cleaning and general expenses and was proposed based on interviews with the owners as well as previous studies. The Ecuadorian currency is US Dollars, whose rate of exchange was considered to be US$ 1 = R$ 2.37, when calculated by the authors (MARCH, 2014).

Table 5, in similar fashion to the table presented for Brazil, presents the calculation sheet for the measurement of the monthly revenue generated from biogas energy production, considering a null Net Present Value, that is to say, the total inflows is equal to the total outflows in the cash flow.

Table 5: Calculation sheet For Financial Viability (Ecuador)

Description	Values	Variation (Crystal Ball)
Volume of waste per day (kg)	2,25	10%
Number of animals	3.440	-
Total volume of waste per day (kg)	7.740,00	-
Total volume of month per month (kg)	232.200,00	-
Conversion rate	0,063	10%
Volume (m3)	14.629,00	-
Conversion rate	60%	10%
Methane Volume (m3)	8.777,00	-
Conversion rate KWh	5,5	-
Total KWh generated	48.274,00	-
Value KWh (Brazil)	US$ 0,30	-
Monthly revenue generated	US$ 14.482,31	-

Source: The Authors (2014).

The value of KWh was measured based on the value of the reference month (MARCH, 2014). A calculation of the number of animals was performed using the tool, the same procedure adopted in Brazil. As such, null NPV is achieved with approximately 3440 animals. For this calculation, the Minimum Rate of Attractiveness (MRA) was used at 4% per year.

This value was calculated based on the profitability of the available investment funds as well as the levels of inflation in Ecuador, which is low (2.7% in 2013, according to the Central Bank of Ecuador) in comparison with Brazil, alongside a risk premium in return for the implementation of capital. Based on this revenue generated, the project cash flow for Ecuador is illustrated in Table 6.

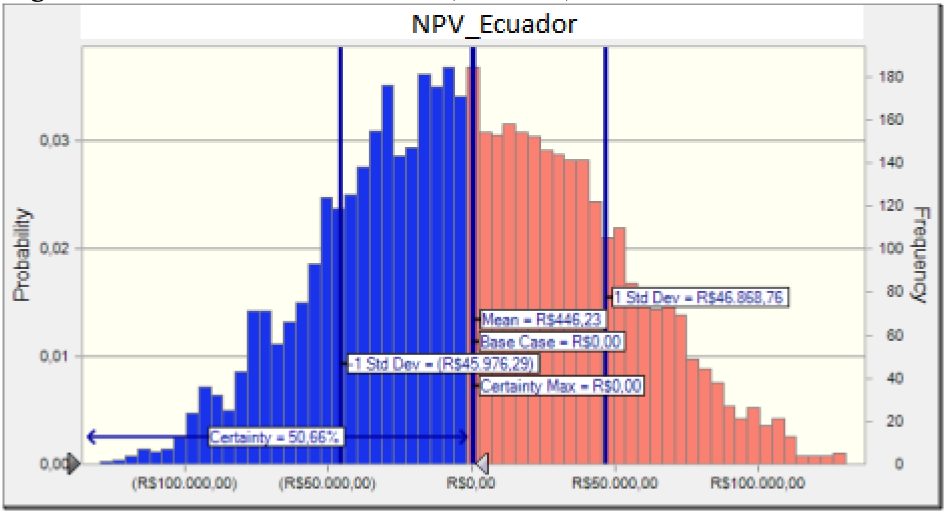
Table 6: Cash Flow (Ecuador)

Month	0	1	2	…	60
Inflows	-	US$ 14.482,31	US$ 14.482,31	US$ 14.482,31	US$ 452.762,31
Outflows	US$1.100.000,00	US$ 860,00	US$ 860,00	US$ 860,00	US$ 860,00
Cash Flow	- US$1.100.000,00	US$ 13.622,31	US$ 13.622,31	US$ 13.622,31	US$ 453.622,31

Source: The Authors (2014).

In the same way as presented in the cash flow for Brazil, the project for Ecuador is also considered over a period of five years, and the last month of the project is also added to the residual value of 40% of the initial investment. From this cash flow, the NPV obtained is approximately null, and the calculated IRR is approximately equal to the MRA presented. That is to say, from the number of animals calculated for financial viability for the implementation of the bio-digester exists, regardless of the variation of the parameters. These premises of the variation of parameters for the Monte Carlo simulation are now considered.

Figure 3: Monte Carlo Simulation (Ecuador)

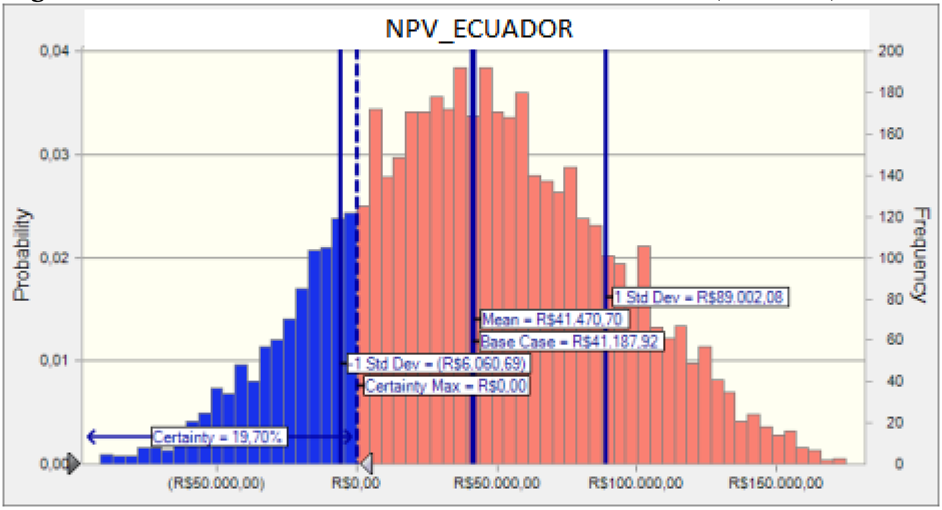


The Monte Carlo simulation was performed with 5,000 interactions and with a confidence interval of 95%. The NPV for the swine waste in Ecuador resulted in a mean value of US$ 446.23, with a NPV minimum of - US$ 132,551.93 and US$ 147,441.75 maximum (with a standard deviation of US$ 46,422.53). The Monte Carlo simulation also indicates that the probability of NPV is less than zero, or the IRR is less than the MRA at 50.66%, thus, we have that p(NPV <0) = p(IRR <MRA) = 0.5066, indicating a remarkably high risk of not recovering the invested capital if the number of animals is kept at approximately 3440 animals. This risk is considered generally to be too high to attract investors.

As in the case of Brazil, assuming the investor can take a maximum 20% risk of losing money on the project, then p(NPV <0) =

p (IRR <MRA) should be at most equal to 0.20. Running again, the Monte Carlo simulation within these parameters, the minimum number of pigs needed to satisfy this premise equals 3620 animals. Figure 4 shows the graph of this simulation.

Figure 4: Monte Carlo Simulation for risk level at 20% (Ecuador)



Within this scenario, the probability that the NPV is greater than zero 0.8030, is found with a 95% confidence interval, and is found between - US$ 99,441.42 and US$ 196,569.85 (with a standard deviation of US$ 47,531.38). Therefore, the chance of losing the invested money is 19.70% whilst this new scenario provides figures of p(NPV <0) = p(IRR <MRA) = 0.1970.

Conclusion

The objective of this research has been to focus on calculating the minimum number of swines that a farm needs in order to have economic viability for the deployment of a bio-digester for electricity generation in the cases of Brazil and Ecuador after assessing the traits of each country. Thus, from the feasibility analysis, with a calculation of Net Present Value and considering all the assumptions of fixed inputs, i.e. a deterministic scenario, we obtained a minimum number of 1,040 swines +1 in Brazil and 3,440 swines in Ecuador.

Then, the Monte Carlo simulation was carried out, with the variation of some parameters. In this new simulation alongside the consideration of a probabilistic setting the calculations demonstrated that in the case of Brazil, the probability that the NPV> 0 is 0.4895 and the probability of the IRR <MRA is 0.5105. Already in Ecuador the probability that the NPV> 0 is 0.4934, and the probability of the IRR <MRA is 0.5066. Within this context, given that p(NPV <0) = p(TIR <MRA) = 0.5105 for the project with 1040 pigs in Brazil and p(NPV <0) = p(TIR <MRA) = 0.5066 for the project with 3,440 pigs in Ecuador, there is a considerably high risk for the investor. We opted to establish, then, from other studies, that the investor accepts a maximum 20% risk of losing money. In this new perspective, the minimum number of pigs needed in Brazil to meet this premise is 1,095 animals, and for Ecuador, taking into consideration the same assumption, the number that we are delivered is 3,620 animals. Therefore, the bio-digester should be deployed after considering a maximum of 20% risk of losing money, with properties that have at least 1,095 pigs in Brazil or 3,620 pigs in Ecuador. The big difference in the number of animals in the two countries is due mainly to the difference in cost of deployment of the bio-digester, which is much higher in Ecuador than Brazil.

In addition to generating cash from the sale of the electricity generated, companies that use bio-digesters contribute to sustainability and corporate social responsibility. In this context, the generation of energy from bio-digesters with the number of animals indicated in this study, Brazil would avoid the emission of 2,520.20 kg of CO2 per year (KEY ASSOCIATES, 2014). Furthermore, in Ecuador, the generation of energy from animal waste would avoid the emitting of 8,336.00 kg of CO2 per year to the external environment (KEY ASSOCIATES, 2014).

Within this perspective, the compensation required, as a result of the avoidance of the emission of greenhouse gases into the atmosphere for Brazil would be the equivalent of saving 15 trees, native to the Atlantic Forest of Brazil and 48 trees for Ecuador (KEY ASSOCIATES, 2014).

This research was limited to the financial viability analysis of energy production via the use of swine waste in Brazil and Ecuador. Thus, it is not possible to generalize the analysis and reflections which were proposed here for example, neither with other animals nor in respect to other countries. This is due to the differences in the cost of electricity, salaries and expenses of employees, as well as the levels of investment needed for the implementation of the bio-digester´s assembly costs and other expenses, such as maintenance. Moreover, the possible revenues from generating carbon credits were not considered when calculating the inflows of the project, nor the use of waste for the manufacture of other products, after the generation of energy. These could be considered as lines of research for any future studies.

It is therefore recommended, that research be carried out in other countries in order to compare the results of this study and perhaps also via the use of waste from other animals. Finally, it also suggested that the inclusion of carbon credit revenues and the manufacturing, for example, of fertilizer from the waste after the energy generation has completed.

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