Software That Assists the Analysis of the Economic Viability of the Installation of Biodigesters in Rural Properties Destined for Milking

Celia Regina Nugoli Estevam¹, Denis Henrique Garcia Bonafé¹, Amanda Aguiar dos Santos¹, Giuliano Pierre Estevam¹ and Antônio Marcos Cossi²

¹. Department of Analysis and Development of Systems, Faculty of Technology of the State of São Paulo, FATEC Araçatuba, Araçatuba 16045-800, Brazil
². Department of Mathematics, State University of São Paulo Júlio de Mesquita Filho, Ilha Solteira 15385-800, Brazil

Abstract: The economic development and disorderly population growth, coupled with the modern society’s lifestyle, are complex processes that share a common denominator: the availability of an adequate and reliable supply of energy. An alternative is sustainable development through alternative sources of energy, such as solar energy, wind energy and biomass. In both the international and domestic markets, biomass is considered one of the main alternatives for the diversification of the energy matrix and the consequent reduction of dependence on fossil fuels. The objective of this work is to develop a linear programming model that helps in the decision making as to the feasibility of the implantation of biodigesters for the production of biogas in rural properties destined for milking. In order to solve the proposed model, the classic simplex method was implemented, in the Java programming language with the aim of obtaining results that can be used to support decision making.

Key words: Renewable energy, biogas, bioenergy.

1. Introduction

In Brazil, in recent years, there has been an increase in the consumption of electric energy. This increase is due to the industrial development and the increase of the purchasing power of the population. In contrast there were no significant investments in electricity generation. About 80% of the electricity consumed in Brazil comes from hydroelectric plants, whose potential in the more developed regions of the country is practically depleted. The great hydroelectric potential of Brazil is concentrated in the North, where the predominant relief is lowland and the ecosystem is fragile. With this, there is great difficulty in using this potential [1].

Faced with this energy problem the research on alternative sources of energy has been taking up increasing space in the scientific community. As for example, wind, solar and biogas energy, derived from biomass biodigestion that is defined as any material that has the property of decomposing by biological effect, i.e. by the action of different types of bacteria.

It should be noted that biomass is one of the sources for energy production with the greatest potential for growth in the coming years. Both internationally and domestically, it is considered one of the main alternatives for the diversification of the energy matrix and the consequent reduction of dependence on fossil fuels. From it, it is possible to obtain electricity and biofuel, such as biodiesel and ethanol, whose consumption is increasing in substitution of petroleum derivatives such as diesel and gasoline [2].

In order to exploit the biomass, biodigesters are used, basically consisting of a closed chamber in which the biomass is fermented anaerobically. The process of
anaerobic biodigestion is one of the alternatives used for the treatment of residues, because it reduces the potential of contamination, produces biogas and allows the use of the waste as biofertilizers. Its use in rural properties for biogas production is in increasing expansion, because its construction is relatively simple.

Biogas can be used both as a fuel for generating thermal energy in boilers and stoves, and for generating electricity, which represents an increase in income for the rural producer, who can invest in other parts of his property [3].

It is important to point out that an energy source exerts influence in several aspects. The most latent is the economic aspect, but the political, social and environmental aspects must be taken into account.

However, the process of implantation of the biodigesters must result from the analysis obtained through the comparison of the economic variables, natural and social observed on the property and therefore we must carry out a careful investigation of the potentialities and limitations within each rural setting and must carry out, therefore a careful work of investigation of the potentialities and limitations within each rural setting.

Due to the great advancement of technologies in the programming areas, the implementation of mathematical models to represent or interpret reality in a simplified way has become increasingly feasible. The model has its reliability by means of its validation in the representation of the real system; which it is representing. The difference between the real solution and the solution proposed by the model depends directly on the accuracy of the model in describing the original behavior of the system, considering the maximum number of variables that influence the analysis.

In the last years, the research in mathematical models seeks to relate the variables that influence the biogas production in different types of biodigesters using pork manure as raw material [4-6].

Until then, the great majority of the authors propose models for the implantation of biodigesters without using the tool of the operational research for economic viability analysis [7-10].

The greatest obstacle for such properties to implant the biodigester is related to knowledge. There are not always qualified people, or even financial resources on the part of the owners to do this analysis. By analyzing the initial price of the deployment, they may end up creating a barrier without being aware that this investment will return in a short time.

With this in mind, we propose to develop a mathematical model using the tool of the operational research that can be used in several rural properties destined to cattle and, together, a software that facilitates and makes accessible the economic viability analysis of the installation of a biodigester.

The use of manure from dairy cattle as a raw material for biodigesters is an interesting option because the cattle before being milked remain in an area that usually has its surface covered with cement. This area has to be constantly washed, so one of the components necessary for biodigestion is included in the process which is the water used to clean the stable. In this way the waste is sent to the interior of the biodigester through channels for the processing of the anaerobic biodigestion. After fermentation of organic matter in the biodigester, we have the biogas and biofertilizer. To transform the produced biogas into electrical energy, a generator-motor set is used, coupled to an electric power generator. Thus, through the combustion of biogas by the engine, the generator turns the biogas into electric energy [11].

2. Mathematical Model

The model proposed in the paper can be described as a standard linear programming problem:

\[
\text{MAX } RL = RT - CT
\]

On what:

\[
RT = (R_{\text{leite}} + R_{\text{biod}} + R_{\text{biol}}) \cdot x
\]

\[
R_{\text{leite}} = V_{\text{leite}} \cdot Q_{\text{leite}}
\]
Software That Assists the Analysis of the Economic Viability of the Installation of Biodigesters in Rural Properties Destined for Milking

3. Materials and Methods

The proposed solution to solve the problem of the feasibility of implantation of biodigesters in rural properties intended for milking is approached through the simplex method and implemented in the Java programming language. Fig. 1 presents the initial screen of the software and Fig. 2 presents data entry.

3.1 Simplex Method

The simplex method was developed in 1947 by George B. Dantzig. It is an algorithm that makes use of a tool based on linear algebra to determine, by an iterative method, the optimal solution of a linear programming problem. The optimal solution of the model is a basic solution of the system, that is, an extreme point the polygon generated by the constraints.

To be started it is necessary to know a basic compatible solution (initial solution) of the system, that is, one of the points of the generated polygon. The
simplex method verifies that the present solution is optimal. If it is, the process is closed. If it is not optimal, it is because one of the adjacent points provides a better value for the objective function than the current one. In this case, the simplex method then changes the point by another that best optimizes the value of the objective function and verifies if this new point is optimal. The process ends when you get an endpoint where all other endpoints provide worse values for the objective function [16, 17].

3.2 Java Programming Language

When it was created by Sun Microsystems, the main goal of this was to be a language for consumer electronics, which means that it should be compact and architecture neutral. Although it has not been very
successful for this objective, when it was used for the web platform it has gained great prominence [18]. According to Ref. [18], the language is based on the Object Orientation paradigm—encapsulation in a software block of data (variables) and methods of manipulation of such data—language allows the modularization of applications, reuse and maintenance the code already implemented. One of the strengths of the language is productivity support, since the Application Programming Interfaces (APIs) provide a large set of ready-to-use features.

One of the main concepts of this language is its portability. The Java language provides a resource, the JVC (Java Virtual Machine) that acts as an intermediary between hardware and software, which circumvents the platform-related problem in which the program will run. This means that software developed and compiled on a specific platform (e.g. Windows) can run on another platform (e.g. Linux) without the need for recompilation or any other developer intervention.

3.3 Data Needed for Economic Viability Analysis

For the calculation to be carried out, the owner must provide some information about the property. Thus, for validation of the proposed model, values were collected together with a rural property that does not have biodigestion systems. It is the São Joaquim farm, located northwest of the state of São Paulo, in the municipality of Araçatuba. Its commercialized products are: milk Type A and Type A Light and also class A butter. Also tested was a hypothetical example (Fazenda X), where the property needs to buy cattle to increase its net income. The property data are shown in Table 1.

### 4. Testing and Results

Two tests were performed for the proposed mathematical model:

Test 1: Using data from Farm São Joaquim mentioned in Table 1.

The computational program presented the following result: the amount of cattle needed to maximize the profitability with the implantation of the biodigester in the property would be 148 cattle, thus generating an implantation cost of $34,304.36; a maintenance cost of $1,909.60; a profit of $2,599.80 in generated electric energy and $361.26 with biofertilizer produced. Even with the costs it is observed that the net income of the property will be $15,855.86. With the amount of existing cattle, which is 170, the owner will have a deployment cost of $39,435.60; a maintenance cost of $2,195.24; a profit of $2,988.66 in electricity generated and $415.30 with biofertilizer produced. In this case, it is observed that the net income of the property will be $18,577.93, as can be seen in Fig. 3.

Test 2: Using the data from Farm X, mentioned in Table 1.

The results obtained from Fazenda X data showed that the property will need to buy 4 heads of cattle to maximize its income with the implantation of the biodigester, that is, it needs to have 74 heads of cattle, thus generating a cost of implantation of $72,350.65; a maintenance cost of $960.58; a profit of $1,307.77 in electric energy generated and $181,72 with biofertilizer produced. The net income of the property will be $7,113.80. The results with the amount of cattle existing, that is of 70, showed that, the property will have a

| Table 1  Property data.     | Farm São Joaquim | Farm X |
|-----------------------------|-------------------|--------|
| Amount hours of confinement | 15                | 15     |
| Amount of livestock         | 170               | 70     |
| Food expenditure ($)        | 10,067.65         | 4,145.50 |
| Price of cattle head ($)    | 1,158.48          | 1,158.48 |
| Liter of milk per head of cattle (L) | 10              | 10     |
| Price of the liter ($)      | 0.37              | 0.37   |
| Amount of employees         | 4                 | 4      |
| Total expenditure on employees ($) | 1,390.18       | 1,390.18 |
| Energy expenditures ($)     | 2,329.37          | 2,329.37 |
| Value of Kwh ($)            | 0.14              | 0.14   |
| Budget for maintenance ($)  | 16,218.72         | 9,267.84 |
| Power installed in kW       | 20                | 20     |

Source: author.
Fig. 3  Results of Farm São Joaquim.

Fig. 4  Results of property X.

cost of implantation of $68,082.91; a maintenance cost of $903.92; a profit of R $1,230.63 in electric energy generated and $171.00 with biofertilizer produced. In this case, it can be observed that the net income of the property is $6,625.10, as can be seen in Fig. 4.

5. Conclusion

Based on the simulations, the validation of the proposed mathematical model can be verified, since the cost with the implementation compared to the net income shows the viability of the project under the economic-financial approach. However, when considering the environmental benefit provided by the project the favorable decision of the enterprise is reinforced.

Acknowledgments

The authors thank the Foundation for Research Support of the State of São Paulo (FAPESP), for the financial support, Process: 2013/25526-5.
References

[1] Coldebella, A. 2006. “Viabilidade do uso do biogás da bovinocultura e suinocultura para geração de energia elétrica e irrigação em propriedades rurais.” Dissertation (MSc in Agricultural Engineering), State University of Western Paraná, Cascavel.

[2] McKendry, P. 2002. “Energy Production from Biomass (Part 1): Overview of Biomass.” Bioresource Technology 83: 37-46.

[3] Deganutti, R., Palhaci, M. C. J. P., Rossi, M., Tavares, B. R., and Santos, B. C. 2002. “Biodigestores rurais: modelo indiano, chinês e batelada.” In 4th Encounter of rural energy. São Paulo, Faculty of Architecture, Arts and Communication, Unesp, São Paulo.

[4] Florentino, H. O. 2003. “Mathematical Tool to Size Rural Digesters.” Sci. Agric. 60 (1).

[5] Nogueira, C. E. C., and Zurn, H. H. 2005. “Modelo de dimensionamento otimizado para sistemas energéticos renováveis em ambientes rurais.” Eng. Agríc. Jaboticabal 5 (2): 341-8.

[6] Walker, E. 2009. “Estudo da viabilidade econômica na utilização de biomassa como fonte de energia renovável na produção de biogás em propriedades rurais.” Dissertation (MSc in Mathematical Modeling) Regional University of the North west of the State of Rio Grande do Sul, Ijui.

[7] Zanin, A., Bagatini, F. M., and Pessatto, C. B. 2010. “Economic and Financial Viability for the Implantation of a Biodigester: An Alternative to Reduce the Environmental Impacts Caused by the Swine Culture.” Custos e Agronegóciosonline 6 (1).

[8] Silva, E. R. P., Navarro, L. L., and Almeida, S. C. A. 2008. “Dimensionamento da produção de biogás a partir de resíduos residenciais, industriais e de matrizes suínas na comunidade de Vila Paciência (RJ).” Brazilian Congress Energy, Rio de Janeiro (Out).

[9] Cervi, R. G., Esperancini, M. S. T., and Bueno, O. C. 2010. “Viabilidade econômica da utilização do biogás produzido em granja suínica para geração de energia elétrica.” Agricultural Engineering Journals Jaboticabal 30 (5): 831-44.

[10] Catapan, A., Catapan, D. C., and Catapan, E. A. 2011. “Formas alternativas de geração de energia elétrica apartir do biogás: uma abordagem do custo de geração da energia.” Custos e Agronegócio 7 (1).

[11] McKendry, P. 2002. “Energy Production from Biomass (Part 2): Conversion Technologies.” Bioresource Technology 83: 47-54.

[12] Utembergue, B. L., Afonso, E. R., and Pereira, A. S. C. 2013. “Manejo de dejetos em confinamento de bovinos de corte.” III Symposium on sustainability and animal science. Accessed Feb. 15, 2018. http://sisca.com.br/resumos/SISCA_2013_020.pdf.

[13] Santos, A. F. da S. 2009. “Estudo da viabilidade de aplicação do biogás no ambiente urbano.” Faculty of Economics of Administration of Ribeirão Preto, Ribeirão Preto. Accessed Feb 25, 2018. http://cetesb.sp.gov.br/biogas/2009/12/01/estudo-de-viabilidade-de-aplicacao-do-biogas-no-ambiente-urbano/.

[14] Cibiogas. https://www.cibiogas.org/.

[15] Barbosa, F. A. 2017. “Confinamento: planejamento e análise econômica.” Accessed Feb. 18, 2018. http://www.agronomia.com.br/conteudo/artigos/artigos_confinamento_analise_economica.htm.

[16] Prado, D. 1999. “Programação Linear.” Belo Horizonte: Operational Research, vol. 1. 7th ed.

[17] Arenales, M., Armentano, V. A., Morabito, R., and Yanasse, H. H. 2007. “Pesquisa Operacional.” Rio de Janeiro: Campus/elsevier. ISBN 10-85-352-145-1454-2.

[18] Deitel, P. J., and Deitel, H. M. 2010. Java Como Programar. 8th ed. São Paulo: Pearson.