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METHODOLOGY OF ECONOMIC EVALUATION OF EXTERNALITY EMISSIONS IN RELATION TO THE VALUE OF ELECTRIC POWER GENERATED BY THE BURNING OF BIOGAS IN THE RURAL ENVIRONMENT

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ABSTRACT

Brazilian cattle raising needs greater automation as a way to improve productivity and at the same time new ways to meet the growing energy demand. Thus, an alternative is to use renewable sources of electric energy such as biogas. This work proposes a methodology for economic evaluation of the externality denominated emissions, originating from the generation of electric energy through the burning of biogas from residues of Brazilian livestock. Thus, an equation was proposed and applied to obtain the value of this externality as a percentage of the value of electric energy, where greater results indicate greater potential for this externality. The results showed that the emissions, assessed as an externality and quantified on the basis of carbon credits can account for up to 69.4% of the electricity price, but if quantified in relation to the social impact of carbon, the externality in reference exceeds the value of electricity, reaching 408.4%. As a result, it is clear that the use of biogas for power generation in livestock can present other valuable products in addition to electricity and, consequently, can add value to livestock activity.

Palavras-chave:
Biomassa
Impactos externos
Energias renováveis
Recursos energéticos

METODOLOGIA DE AVALIAÇÃO ECONÔMICA DA EXTERNALIDADE EMISSÕES EM RELAÇÃO AO VALOR DA ENERGIA ELÉTRICA GERADA PELA QUEIMA DO BIOGÁS NO MEIO RURAL

RESUMO

A pecuária brasileira necessita de maior automação como forma de melhorar a produtividade e simultaneamente novas formas de suprir a demanda energética crescente. Assim, uma alternativa é utilizar fontes renováveis de energia elétrica como o biogás. O presente trabalho propõe uma metodologia de avaliação econômica da externalidade denominada emissões, oriunda da geração de energia elétrica por meio da queima do biogás proveniente de resíduos da pecuária brasileira. Para isso, foi proposta e aplicada uma equação para obter o valor dessa externalidade em percentual do valor da energia elétrica, onde maiores resultados indicam maior potencial dessa externalidade. Os resultados demonstraram que as emissões, avaliadas como um externalidade e quantificada com base nos créditos de carbono pode valer até 69,4% do preço da energia elétrica, mas se quantificada em relação ao impacto social do carbono, a externalidade em referência ultrapassa o valor de energia elétrica, chegando a 408,4%. Com isso, tem-se que a utilização do biogás para a geração de energia na pecuária pode apresentar outros produtos valiosos além da energia elétrica e que, consequentemente, podem agregar valor à atividade pecuária.

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INTRODUCTION

Brazilian livestock production is highly expressive on the world stage. It ranks the second position in beef and chicken production on the planet, and the fourth in pork production (BRAZIL, 2019). Such production contributes to the generation of jobs and income in the countryside and positively impacts the country's economy (REIS, 2017). However, Brazilian cattle breeding needs investments and modernization, as according to Latawiec *et al*. (2017), this activity has low productivity besides being marked by environmental degradation.

Therefore, the need to modernize the sector to meet the growing demand for food, increase profitability, and to reduce the degradation of the environment becomes imperative (OGINO *et al*., 2016). However, the modernization process, which can be achieved through automation processes, may result in greater dependence on electrical energy (SHINE *et al*., 2018). Thus, solutions that can supply the growing energy demand of livestock in a sustainable and economically viable way are essential to enable a greater development of the sector.

In this context, the use of renewable sources to supply the livestock's energy demand can be assertive. In particular, livestock residues can give rise to biogas, which is a gaseous fuel with a high energy content composed mainly of methane and carbon dioxide. The burning of biogas has many advantages in addition to the possibility of generating electric power, as it can reduce greenhouse gas emissions from livestock, since it transforms methane into carbon dioxide, whose environmental impact is lower than that of methane (SOUZA *et al*., 2004).

In this sense, the generation of electrical energy through the burning of biogas has additional characteristics to the generation of electrical energy that can result in many advantages of using this technology in rural areas, such as the reduction of greenhouse gas emissions. These external impacts, whether positive or negative, are defined as externalities and can be quantified in economic terms (MARTINEZ-SANCHEZ *et al.,* 2017).

As a result, it may become very relevant to account for the externalities of electricity generation by biogas. This is because such externalities can be positive, therefore, resulting in a greater possibility of viability for the implementation of this technology in Brazil (MARTINEZ-SANCHEZ *et al.,* 2015). The accounting of externalities can allow a greater understanding of the profitability of biogas for the generation of electric energy. Jensen and Skovsgaard (2017) concluded that the externality associated with greenhouse gas emissions can improve the viability of biogas. Thus, externalities may enable the generation of electric power as a way to assist the domestic livestock that, in their majority, provide low economic returns (LATAWIEC *et al*., 2017).

The objective of this study was to develop a methodology to economically assess the externality related to emissions from the generation of electricity based on its value, by means of burning biogas from Brazilian livestock waste.

MATERIAL AND METHODS

The objective of the present methodology was to estimate the economic value of the emissions externality from the burning of biogas based on the price of electricity available in rural areas. The emissions externality refers to the environmental impact caused by the emissions of gases that cause the greenhouse effect. In order to carry out this estimate, it was considered that biogas from the anaerobic digestion of livestock residues can be burned to generate electric power.

The economic evaluation of the externality was carried out considering that the burning of biogas may reduce the environmental impact of pollutant emissions as the emission from methane gas is more harmful than that caused by carbon dioxide. It has to be said that this reduction in emission can be equated and calculated economically, since the price of carbon credits (ARAUJO *et al.,* 2019) or the social impact of carbon dioxide (ESCOLHAS, 2020) are known. Therefore, the value of externality was estimated as it is known the potential for generating electricity from biogas, the value of electricity and the value of emissions avoided through the estimates: price of carbon credits or social impact of carbon dioxide carbon.

Equation 1 enabled to propose an estimate of the externality value (V_E), *i.e*., the externality

price calculated as a percentage of the electric power price (%). Higher E_V value indicates that the externality has a greater value in relation to electric power, which emphasizes the importance of this externality. It was considered that in the composition of biogas only the two largest components, CH_4 and CO_2, and that during the burning of biogas, the same amount of CO_2 in number of molecules is obtained from CH_4.

$$V_E = \frac{C_C\, R[(N\, D_{CH4}\, C_{CH4}) - (D_{CO2})]}{P_{EE}} \quad (1)$$

In Equation 1, C_c is the carbon credit value where data from January 2020 equal to 4.92 US$/ton (INVESTING, 2020) were used. R is the amount of electrical energy that can be obtained by a certain volume of biogas, this ratio corresponds to 1.428 kWh/m^3 (DEGANUTTI *et al*., 2002). N is the polluting impact with respect to the greenhouse effect between a ton of methane (tCH_4) and a ton of carbon dioxide (tCO_2); the value was adopted at 24.5 (GOHAR; SHINE, 2007). The d_{CH4} and d_{CO2} are the densities of CH_4 and CO_2, 0.716 kg m^{-3} and 1,965 kg m^{-3} respectively, under normal conditions of temperature and pressure. C_{CH4} is the percentage of CH_4 that the biogas presents, considered equal to 65% (YANG *et al*., 2019). P_{EE} is the price of electric power in rural areas, which is approximately 95.51 US$/MWh, without considering the taxes that are estimated at 40% (CEMIG, 2020).

Based on the capacity of the biogas burning to reduce emissions from livestock, the percentage value of this externality grounded on the price of electricity was quantified on the basis of the current carbon credit value. The result obtained through Equation 1 was recalculated, considering the replacement of the carbon credit value (Cc) by the value of the social impact of tCO_{2e} estimated at 28.94 US$/$tCO_{2e}$ (ESCOLHAS, 2020).

RESULTS AND DISCUSSION

Through Equation 1, we obtained that the emissions externality may account for 69.4% of the electric power price without taxes, if quantified on the basis of carbon credits, as well as Araujo *et al.* (2019). If taxes are considered at 40% of the electric power price, the externality would correspond to 49.6% of the electricity price. This result demonstrates that even with the high value of the electric power in Brazil, the externality in question may represent a product of value equivalent to approximately half of the amount of energy generated.

Knowing that carbon credits may not represent the real damage caused by emissions, since the value has suffered sharp declines since the end of the Kyoto Protocol, the externality in relation to the social impact of greenhouse gas emissions has also been quantified. It was found that the externality exceeds the value of electricity, reaching 408.4% of the value of energy without taxes or 291.7% with taxes on the value of electric power. These values are higher than those found with the use of carbon credits, as it is considered the social impact, therefore the higher values of this externality are justified because the social effects of tCO_2e were quantified.

The results obtained in this experiment demonstrate that the value of externalities can significantly influence the feasibility of using biogas to generate electric power since a single externality such as that evaluated in this study may value more than the electricity itself and, consequently, positively impact the livestock. There are examples of considering externalities and their effects in the most diverse sectors, such as the feasibility analysis of LED light bulbs and the disposal of solid waste (JONES, 2018; MARTINEZ-SANCHEZ *et al*., 2017).

CONCLUSION

- This work demonstrated that the emissions externality from the use of biogas for the generation of electric power can correspond to 49.6% of the price of the electric energy generated by the burning of biogas, reaching 408.4%. Such values reinforce the importance of externalities arising from the use of biogas for the generation of energy in rural areas, which may provide livestock with development opportunities with greater sustainability. In addition, new methodologies for economic evaluation are necessary as a way to enable the validation and consolidation of the results

obtained in the experiment.

- Finally, if we consider more externalities related to renewable energy, the viability of these new sources can be increased, since renewable sources tend to have positive characteristics or advantages that can be reflected in a predominance of positive externalities. Thus, it can be inferred that it is relevant that externalities are included in the analysis of the feasibility of investment and implementation of new installations from renewable sources, allowing the execution of projects that were not viable through traditional analysis.

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