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Review

Optimal allocation of sugarcane bagasse for producing bioelectricity and second generation ethanol in Brazil: Scenarios of cost reductions

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ABSTRACT

The consolidation of second generation ethanol will provide a greater amount of ethanol without increasing sugarcane acreage, but two technologies have emerged that use sugarcane bagasse as a feedstock: the generation of bioelectricity and second generation ethanol. As a result, a new discussion has arisen for the future configuration of the sugarcane industry: should bagasse be used to generate bioelectricity or produce second generation ethanol? Due to the high volatility of prices, for both electricity and anhydrous ethanol, the decision is complex, and higher volatility of price is associated with greater risk in this decision. This article presents a bi-objective optimization model to decide efficiently the percentage of the available sugarcane bagasse that should be allocated to each of these options in order to maximize the average return and, at the same time, minimize the risk inherent in price level volatilities. The results for four possible scenarios are presented; it is concluded that the scenario that presents a bioelectricity production cost of US$ 50/MWh and a cost of second generation ethanol production of US$ 0.30/liter has a higher return and lower risk to the investor. In this scenario, the allocation of bagasse for second generation ethanol production is 84%.

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1. Introduction

To reduce the greenhouse effect and consequent global warming, it is necessary to reduce the use of fossil fuels and increase the share of renewable sources in the energy mix of countries; this issue is being widely discussed by authorities worldwide.

Brazil, being a country that is located between the tropics of Cancer and Capricorn, receives a high level of solar radiation during the year and has water and soil in large quantities: ideal conditions for the production of sugarcane.

Sugarcane is one of the major cultures of the world, grown in more than 100 countries, but Brazil and India together generate slightly more than half of all sugarcane produced in the world.

The cultivated area of sugarcane for the 2014/2015 crop in Brazil was approximately 9 million hectares with a production of 634.77 million tons of sugarcane; the Southeast region accounts for 62% of production [1].

The production of ethanol and sugar from sugarcane is performed in agro-industrial units. There is a strong similarity between these two processes because they use the same extraction equipment (mills or diffusers) with differences only in the final part of each process.

Bagasse is a by-product of this production, and is currently being used to produce steam in boilers. The primary steam (high pressure) is used to generate power for milling, pumping and generation of electricity. The secondary steam (low pressure) resulting from the turbine exhaust is used as a heat source for heating, evaporation, baking and distillation.

Cogeneration, which, a priori, was intended for energy self-sufficiency of individual plants in the sugarcane industry, became a strategic source of bioenergy with the introduction of new technologies that use high-pressure boilers [2–4]. In Brazil, bioelectricity from sugarcane is generated during the sugarcane harvest, which coincides with the dry season when reservoirs are at lower levels, thereby complementing hydroelectric generation. Another advantage of this energy source is that in can be generated next to consumption centers, thus eliminating the use of large transmission lines.

Both ethanol and bioelectricity have been gaining prominence in the Brazilian energy matrix, representing a great investment opportunity for owners and shareholders in the sugarcane industry. Fig. 1 shows the monthly growth in the demand for ethanol and electricity in Brazil between the 1979 and 2016; this growth demonstrates the strategic importance of both products to Brazil's economic development.

The favorable outlook for growth in the demand for ethanol and electricity led to the creation of more efficient production units, and encouraged research and development of new technologies [5–10]. Thus, in recent years, there has been an increase in the export of electricity to consumer systems and the beginnings of commercial production of second generation ethanol.

According to UNICA [11], the Brazilian sugarcane industry currently holds 7.5% of the power granted by the Brazilian Electric Energy Agency (ANEEL), which makes it the third most important energy source in the country, behind only hydropower and fossil fuels. The industry has 387 plants authorized by the Brazilian Agency of Petroleum, Natural Gas and Biofuels (ANP). Most of these plants produce bioelectricity for their own consumption (13.2 TWh), but 170 of them currently export surplus bioelectricity to the network for consumers (19.4 TWh), and the trend in coming years is to increase the export of bioelectricity surpluses.

In turn, from 2003 onward, with the introduction in the Brazilian market of *flex-fuel* vehicles, which use ethanol and/or gasoline, there was an increase in the consumption of ethanol and a reduction in gasoline consumption by more than half. Another reason for the increased demand for anhydrous ethanol was the policy adopted by Brazil and many other countries to increase the mix of ethanol in gasoline; currently, in Brazil, it is mandatory to have a mixture of 27% ethanol in gasoline.

Given this perspective of increasing demand for anhydrous ethanol and the need to increase the production capacity of the plants, it is necessary to increase the productivity of liters of ethanol per hectare of sugarcane planted. To this need, research has been conducted to enable the commercial production of cellulosic ethanol from sugarcane bagasse: so-called second generation (2G) ethanol.

Currently, Brazil has a predominantly hydroelectric matrix, a predominance that has been declining periodically, which indicates that the hydropower-based generation model with large reservoirs is depleting. Faced with this process of change in the Brazilian electrical matrix and thinking about the security of the electrical energy supply, there is a need for growth in the production of bioelectricity in the coming years. On the other hand, with growth in the number of flex-fuel vehicles and the obligatory mixing of ethanol with gasoline, it is necessary to increase the production of ethanol with the use of new technologies such as second generation ethanol.

The bagasse from sugarcane is a residue of ethanol and sugar production, and it is used as an input for both bioelectricity production and for the production of 2G ethanol. Under this new scenario, the owners and shareholders in this sector face the following dilemmas: *i)* which compensates more, making an investment in a bioelectricity unit or a 2G ethanol production unit; *ii)*

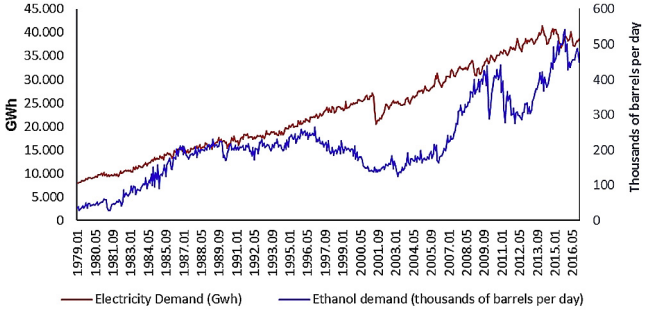

Fig. 1. Demand for ethanol and electrical energy.
Source: Own elaboration with the data of the EPE[1] and ANP[2]

[1] EPE – Energy Research Company: http://www.epe.gov.br/mercado/Documents/Box%20Mercado%20de%20Energia/.

[2] ANP – National Agency of Petroleum, Natural Gas and Biofuels: http://www.anp.gov.br/wwwanp/dados-estatisticos/and http://www.ipeadata.gov.br/.