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Cogeneration of electricity in sugar-alcohol plant: Perspectives and viability

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ABSTRACT

This study was conducted at a sugar-alcohol plant located in Nova Alvorada do Sul city, Mato Grosso do Sul State (MS), Brazil, with the objective to discuss the economic viability of electricity cogeneration using sugarcane bagasse for sale of surplus electricity for concessionaires through of the Sistema Interligado Nacional (SIN). Net Present Value (NPV) was used to calculate the economic feasibility of comparing the invested initial capital and the result of the sum of the cash flow at the end of the period. It was observed that the investment can produce financial returns when the production of electricity by the plant is above 40 MW h or that the MW h price is traded above the USD$ 44.00. The results showed that the cost of production of 1 MW h is USD$ 29.04, a competitive value compared to other small power plants, which makes it an excellent alternative both for the company's financial complementarity as well as for the production of electricity of the plant, with environmental and socioeconomic advantages.

1. Introduction

The great challenge of human beings worldwide is to produce clean, cheap and environmentally correct energy in order to have sustainable development based on three pillars: economic, social and environmental. The sugarcane has great potential in the supply of clean energy, both in the production of ethanol and sugar, as well as electricity produced by burning bagasse [1,2].

With the change from the sugarcane harvesting system, from manual with burning, to mechanized harvesting, there was a considerable increase in organic material in the field, especially of straw and pointers. The straw is currently left in the field as organic material for soil protection, but could also become the raw material for energy production as well as to produce the second generation of ethanol. However, the amount or percentage of straw that must be left in the field for proper soil protection is not yet clear [3].

Sugarcane biomass is a renewable source of energy, standing out due to its importance in the economic context of the sugar and ethanol industry with cogeneration of energy for both the industry itself and for the sale of surplus as electricity [4–7].

Cogeneration of electric energy using sugar cane bagasse is important because it helps to save water in the reservoirs of hydroelectric power plants in the harvest period, since Brazil has a predominant hydric energy matrix, due to the great wealth of rivers, but is presently with shortage of water and the period of greatest generation of this modality of energy coincides with the dry season. Each ton of sugar cane ground for the production of sugar and ethanol generates, on average, 250 kg of bagasse and 200 kg of straw and pointers [8,9].

Biomass has a positive effect on the environment because it can be used for energy production. Fossil fuels, such as coal and oil, are considered non-renewable because they will end in the near future [10]. As a developing country, Brazil emerged as the second largest ethanol producer in the world, after the United States of America, reaching a volume of 26.6 billion liters in the 2013/14 crop in a total of approximately 9.0 million liters. hectares of cultivated area [11,12].

In terms of electricity, in 2012 Brazil had the largest share of renewable sources in the world, accounting for 44.1%, while the global rate reached 13.2%. Of the renewable sources, hydroelectricity in 2015 represented 66.1% of the Brazilian energy matrix, followed by thermoelectricity with 19.0%, biomass with 9.1%, nuclear 1.5% and wind power 4.3% [13]. The biomass energy production sector (sugar cane bagasse) has existed for decades, mainly in the state of São Paulo (Brazil), where studies of several authors on the subject have been identified. The sale of cogenerated electricity by this sector has become viable with the reform of the electricity sector, encouraging new investments in the private sector [14–18].

According to [19], the state's presence is critical for regulatory issues, mediation, and new projects that took place with resolution ANEEL 482, of 2012, that regulated the sale and distribution of surplus electricity production through the Sistema Interconectado Nacional

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(SIN). This resolution makes it possible for cogeneration to have greater participation in the brazilian energy matrix, an important alternative energy in times of energy supply reduction.

For [16] the burning of bagasse in steam boiler furnaces is widely performed by the mills to supply their own consumption of thermal and electric energy in the industry, providing the privilege of self-sufficiency, a nonexistent condition in most industrial activities. The sale of surplus electricity through cogeneration has been perceived as a lucrative business by entrepreneurs in the sucroenergetic industry, with return periods of relatively low investment, insignificant environmental impacts, and some regulatory advantages over conventional sources [13]. Another advantage is the possibility of providing alternative energy to local traders, prioritizing the care of small subsidiaries with low transmission cost.

The state of Mato Grosso do Sul (MS), which is highly competitive in the sugarcane industry due to its strategic location between potential markets such as Mercosul and large Brazilian consumers, is one of the largest producers of ethanol and sugar in the country, with a large area of agriculture, favorable to the cultivation of sugar cane. In MS, 22 plants are active and only 9 of them supply electricity over the sale [20,21].

Second [22,23], the economic viability of a cogeneration enterprise of electricity depends on factors such as the sale price of electricity and ethanol for the consumer market, cost of implementation of sugar-energy plant, cost of electricity generation, taking into account the energy security provided during the dry season. But the problem is to answer the following questions of research: How much energy has to be sold by the unit in order to pay for the investment? Is the cost of production competitive compared to other similar sized generation units?

The general objective of this study was to analyze the economic feasibility of producing electricity from sugarcane bagasse in the MS State and to compare production costs with other similarly sized power generation systems. As specific objectives to study two scenarios: 1) analyze the economic viability of the sale of surplus, increasing the electricity to the energy matrix of the State; 2) analyze the feasibility of electric power generation only for consumption.

2. Material and methods

This study was developed in so-called Sugar-Alcohol Plant Santa Luzia of the ETH Bioenergy group, located in Nova Alvorada do Sul city, from October 2012 to June 2013. The methodological approach was exploratory and descriptive through data collection near the center of advanced plant operations.

The Sugar-Alcohol Plant Santa Luzia is part of the ETH Bioenergy group located in the center of MS State, along with the Sugar-Alcohol Plant Eldorado in Rio Brilhante city (MS), which, together have a production capacity of 570,000 MW h and work on the insertion of electricity surplus in the SIN network.

The unit began its operations in the state in 2009 with an investment of USD$ 171 millions, destined to the production of ethanol and USD$ 31 millions to the production of electricity by burning sugarcane bagasse–bioenergy. It has an installed capacity for annual production of 64 million liters of ethanol, milling of 6 million tons of sugarcane, and production of 518,000 MW h of electricity per year. In terms of exploiting the electricity. The company operates as an independent power producer in a free trade environment market.

The MS State is served by the Empresa Energética de Mato Grosso do Sul (Grupo Energisa S/A), subsidiary of the Agência Nacional de Energia Elétrica (ANEEL), to operate the electric power system. The Grupo Energisa S/A has an installed capacity of 4600 MW h, with an energy matrix constituted predominantly of roughly 77% of hydraulic sources. The power supply is executed by the core network consisting of a 230 kV system owned by the Porto Primavera Transmitter, in addition to transmission systems of 230 kV owned by Eletrosul Centrais Elétricas SA [24].

To calculate the economic viability of cogenerating electricity the methodology described by [25], was used with the necessary adaptations made to the sugarcane bagasse, which sustains that the cost of production of electricity is directly related to the capital invested in the construction and maintenance of equipment directly involved in the production of electricity. Therefore, two scenarios were used: the scenario 1) assumes that the unit sells all its surplus production at a fixed cost, and scenario 2) in which it is assumed that only the energy generated for consumption in the unit itself is marketed at a fixed price, without participation of surplus energy.

Remembering that the objective is to answer the following questions: How much energy has to be sold by the unit in order to pay for the investment? Is the cost of production competitive compared to other similar sized generation units? To compose the other variables in the calculation a discount rate of 8% (cost of investment) was considered, which is the rate applied to biomass projects; as well as the federal government's usual financing rate for agricultural production activities [19,25].

The amortization period for the investment in question was of 20 years, as reported by ETH Bioenergy, term applied to the Sugar-Alcohol Plant Santa Luzia – objective of this work.

According to [25], the Capital Recovery Factor (CRF) is given in Eq. (1).

$$CRF = \frac{j \times (1+j)^{n}}{(1+j)^{n-1} - 1} \tag{1}$$

Where j = discount rate (% year^{-1}), and n = years to amortize the investment.

Thus, determining the cost of electricity production (CE), via cogeneration, using the sugarcane bagasse, is determined by Eq. (2).

$$CE = \frac{ACG + ACB}{EP} \tag{2}$$

Where ACB = annual cost of sugarcane bagasse (USD$ year^{-1}), EP = electricity production using sugarcane bagasse (MW h year^{-1}), and ACG = annual investment cost of the motor-generator set (USD$ year^{-1}), which is divided into two parts: ACG = ACT + ACB, where ACT is annual cost of the turbo generator used and ACB is annual cost of the boiler used.

The annual investment cost of the turbo generator (ACT) is determined by Eq. (3).

$$ACT = TCI \times \left(CRF + \frac{OM_1}{100}\right) \tag{3}$$

Where TCI = turbo generator annual cost of investment (USD$ year^{-1}), CRF = capital recovery factor, OM_1 = costs of operation, maintenance and depreciation of investment in the turbo generator (% year^{-1}), with $OM_1 = \frac{OM}{TCI}$ where OM = annual costs of operation, amortization and plant maintenance (USD$ year^{-1}).

The annual cost of investment for the boiler (ACB) is given by Eq. (4).

$$ACB = BCI \times \left(CRF + \frac{OM_2}{100}\right) \tag{4}$$

Where BCI = boiler annual investment cost (USD$ year^{-1}), OM_2 = cost of operation and maintenance in relation to the cost of the investment of the boiler, with $OM_2 = \frac{OM}{TCI}$.

The annual cost of sugarcane bagasse is determined by Eq. (5).

$$ACB = CB \times BCB \tag{5}$$

Where CB = cost of sugarcane bagasse by the ton (USD$ t^{-1}), and BCB = sugarcane bagasse consumption by the boiler (t year^{-1}).

To calculate the electricity production (EP), Eq. (6) is used.

$$EP = Pot \times T \tag{6}$$

Where Pot = nominal power of plant (MW), and T = annual plant