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# Energy balance analysis of the Brazilian alcohol for flex fuel production

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ABSTRACT

This work refers to a case study on sugar cane mill from Sao Paulo State, in Brazil. It will be analysed the financial benefit acquired through sugar cane bagasse usage as energy source, studying the transformation of this inlet into electrical power, highlighting the greenhouse gas emissions throughout the manufacturing processes of sugar and alcohol. Also, a relationship between power generated and gases emitted will be established and a financial analysis of the project cash flow through the analysis of net present value (NPV), internal rate of return (IRR), and payback will be done. The high profitability calculated on Santa Candida Mill was evaluated, which becomes even greater when implementing the cogeneration system. This one may also consider the sale of surplus energy and carbon credits as two more products to sell to the plant.



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## 1. Introduction

Climate changes around the world due to the concentration of greenhouse gases (GHGs) in the atmosphere, thus it was necessary to take action to minimize this serious problem.

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was held. The approach in this convention is

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fundamentally changing the interaction with the solar atmosphere, because the layer formed by gases prevents the radiation from the Earth's surface to release space. This problem was caused by man during the Industrial Revolution, increased agriculture, transportation and use of fossil fuels. This convention was the first major step in the debate on the steps that should be taken in relation to the environmental problems of world order, according to [1].

As a result, in 1997, targets were established through the Kyoto's Protocol to reduce emissions of greenhouse gases, as well as to implement mechanisms to achieve the reduction in the period between 2008 and 2012 [2].

The main goal is to have them develop projects that result in the mitigation of greenhouse gases, or increase in the removal of $CO_2$ from the atmosphere, compared to investments in new technologies and more efficient, thus replacing the fossil energy sources, especially for renewable energy [3].

The following are considered greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulphur hexafluoride ($SF_6$), the hydrofluorocarbons' family (HFCs), and the perfluorocarbons' family (PFCs) [4].

The clean development mechanism (CDM) allows countries in development to participate and work toward sustainability (which makes Brazil a highly attractive country for new projects), besides being a source of funds (Certified Emission Reductions—CERs), and provide a vast scientific knowledge in new technologies [2].

CERs trading is done in the 'over the counter market' of BM&F (Brazilian Mercantile and Futures Exchange), or occur through the intermediation of financial institutions through electronic auctions [5].

Brazil is the third country in the world with amount of gas emission reduction, about 330,722,468 t of $CO_2$, corresponding to 6% of world total. The first one is China with 2257,037,342 t of $CO_2$ and the second is India with 1345,998,122 t of $CO_2$ [6].

Actually, Brazil has used many different sources of renewable energy, such as wind power, solar energy, wave power, tidal power, and biomass, which is studied in this work.

Biomass is made from waste reuse, i.e. for industrial cogeneration. Firewood, rice husk, wood remains, and sugar cane bagasse are example of biomass. Sugar cane bagasse originates from sugar and alcohol production process in sugar cane sector, through its burning in high pressure boilers, which produces vapour that is used for consumption (cogeneration) and electricity and, in some cases, surplus is sold to the grid [7].

Sugar cane bagasse is biomass with greater representation in the Brazilian energy matrix, and it is responsible for the supply of thermal, mechanical, and electrical energies in sugar and alcohol production facilities, through cogeneration [8].

Besides the production of enough electric power for own industrial consumption (almost all Brazilian mills are self-sufficient), cogeneration provides the generation of surplus electric power, depending on the technology used. In contrast to what happened at the beginning of PROALCOOL—National Alcohol Program (1975), when the sugar cane bagasse was considered undesirable, being burned in inefficient low-pressure boilers, today many plants already use energy efficient equipment and, besides supplying its own energy demand, sell the surplus electrical power to the grid [9,10].

The results show that $CO_2$ is the gas that is most emitted during the life cycle of alcohol; it should be beyond the burning of sugar cane bagasse in boilers, the intense use of diesel in trucks, and agricultural machinery [11,12].

The burning of biomass in sugar cane mills is made directly in boilers and their thermal energy is used to produce steam, which powers the turbines for mechanical drive of process, and also in turbines those generate electric power. The steam that leaves these turbines will be used to meet the needs of production process [13]. According to [5], one tonne of sugar cane result in about 280 kg of bagasse (50% of humidity), whose burning produce about 450–500 kg of steam (temperature rate of 300 °C and pressure of 21 bar).

Note that the biomass use is increasing in the Brazilian and world energy matrices as shown in the information from the Brazilian Energy Review—The Financial year 2013 [14].

According to [14], biomass overcomes hydroelectric plants coming close to the supply of petrol and derivatives, which shows the Brazilian commitment to the environment, investments in new technologies and sustainability of cogeneration.

In the sector composition of final energy consumption, the energy sector had the highest growth rate of 11.6%, driven by thermal use of sugar cane bagasse in the alcohol production [14].

The clean development mechanism (CDM), launched under the Kyoto Protocol is intended to internalize environmental externalities and to help developing countries achieve their developmental objectives, employing cleaner, albeit possibly more expensive, technologies, inter alia creating markets for trading of emission reduction certificates (certified emission reduction—CER) [15].

The CDM includes afforestation projects as possible instruments to reduce global atmospheric $CO_2$ and these projects have also the potential to combat regional environmental problems like land degradation and desertification [16].

Several works had mentioned CDM development and $CO_2$ mitigation, highlighting their characteristics [17–24], usual methods [25–32], re-use of waste from other industries [33,34], case studies [35–40], and carbon credits market [41–43].

Financial techniques and their applications had been evaluated, i.e., NPV for evaluation of the covariance of historical data [44], maximization the NPV of the project to the firm [45–47], methods and techniques used to evaluate the economic desirability of projects (including NPV, IRR, payback, and others) [48–52], minimisation of IRR [53], case studies on IRR [54,55], and payback methods of investment appraisal [56,57].

This work refers to a case study on sugar cane mill from Sao Paulo State, in Brazil. It will be analysed the financial benefit acquired through sugar cane bagasse usage as energy source, studying the transformation of this inlet into electrical power, highlighting the greenhouse gas emissions throughout the manufacturing processes of sugar and alcohol.

Also, a relationship between power generated and gases emitted will be established and a financial analysis of the project cash flow through the analysis of net present value (NPV), internal rate of return (IRR), and payback will be done.

## 2. Materials and methods

The study proposes a comparative analysis using NPV, IRR and payback of proposed scenarios (no plant energy self-sufficiency; plant with energy self-sufficiency, without selling the surplus; plant with energy self-sufficiency, with sale of surplus; and implementation of CDM) based on information from Santa Candida Mill, a sugar cane industry. The following information is necessary:

- Estimated time of harvest;
- Power capacity of the mill, in MW
- Power surplus, in MW;
- Energy consumption, in MW h;
- Purchase price for each MW h;
- Retail price for each MW h;
- Index for projection;
- Initial investment;
- Investment suitability guidelines for CDM;