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Research Article

Integration of a Sugar mill, an Ethanol Distillery and a Single Cell Protein Plant Energetically

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ABSTRACT

This paper reported an analysis for an energy integration of a Sugar Mill of a milling capacity of 6900 t/d of cane, an alcohol distillery of 500 Hl/d and a Single Cell Protein plant of 10 t/d is performed becoming a Bio refinery complex. All based on an option in which sugar mill supplies steam and electricity to satisfy needs of each plant during season and ensuring- at this time–enough surplus bagasse and straw, to cogenerate and satisfy steam and electricity demands of annexed plants in off season period. This way it was proven that a sugar mill could satisfy energy demands of these plants and also deliver 6,85 MW-h to national grid during milling season. In addition, 1054 t/d of surplus bagasse was obtained, that together with collected straw from cane harvesting , guaranty complex energy demand, for operating 100 days in off season , at designed production levels of all installations and delivering a surplus of 14,18 MW-h to national grid. With energy integration, Sugar Mill-Distillery-Single Cell Protein (SCP) plant production costs are reduced, because of saving energy consumption, in addition of eliminating all related emissions and environment impacts. A total cost saving gets US $ 3,065,385.00 CUC at harvest season. In addition to this an additional income to milling enterprise is added by selling electric energy to national grid (price to be determined by contract).

Keywords: Surplus bagasse; Cogeneration; Energy integration; Biorefinery; Ecofriendly operation

INTRODUCTION

During last decades, mankind has become more and more aware of three main problems that afflict survivor of our planet: food shortages, energy deficit and environment preservation [1]. Solving these problems has led governments to establish policies aimed to achieve sustainable development, conceiving and promoting strategies and actions on saving and efficient use of energy based on renewable sources that reduces dependence on fossil fuels, without affect crop lands destined to food production, being ecofriendly.

When analyzing evolution it became clear that Sugar industry has had in energy its key factor of technological development. Needs of a systematic demand of effectiveness drove it to ensure more energy efficient systems, transformation of technology, increase of yields and obtaining higher quality sugar [2]. Sugar production and use of associated energy is increasingly a matter of greater interest and attention, as its possibilities make it an element of enormous appeal in a purpose of solving national energy deficit, diversifying sugar production and promoting its economic viability.

Sugar agro-industry is one of more significant renewable energy sources in Cuba, since sugar cane, besides being a main crop, is a most efficient live collector of solar energy. Milling sugarcane does not only imply obtaining of sugar, but also its revaluation by production of higher added value derivatives, taking advantage of co-products obtained in its processing, [3]. In short, sugarcane agro-industry can produce: food (sugar), bioenergy, and a solid source of raw materials for a very wide.

Current energy crisis is driving sugar industry to become an agroindustrial complex where production of energy, mainly bioelectricity for sale to national grids is a business of constant

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and rapid growth [4]. Sugar mills manage a significant quantity of biomass, coming from sugarcane, sufficient to supply necessary energy for sugar production process and its derivatives, generating in addition an electric energy surplus for sale to national grid [5].

Such possibilities make agroindustry an important strategic component of Cuban economy. Sustaining, an ecofriendly food production, making important contributions to diversification of agro production. Delivering significant amounts of surplus energy (electricity to the national system),. It makes a question of medium and long range strategy to achieve actual integration among its plants to enhance their production, take full advantage of raw materials and meet energy needs in a balanced way, contributing at same time to improve Cuban energy matrix by a sustainable and solid electric energy component without fossil fuels.

This challenge requires modifications in steam generation sector with installation of many modern boilers to reach higher levels of working pressure (minimum 42 bar) and more efficient turbo-generators (extraction-condensation), for a better use of steam [6].

This work analyzes an agroindustrial complex formed by a Sugar Mill, an Ethanol Distillery and a Single Cell Protein protein plant, evaluating from integral point of view association of 3 plants and an influence of this integration over productions obtained.

MATERIALS AND METHODS

For a reference case study, a sugar mill with annexed distillery and single cell protein plant was taken. , where sugar mill delivers molasses to distillery for dehydrated ethanol production and residual vinasse generated is used as a carbon source for SCP production.

As a conventional case was assumed an energy integration in harvest period when sugar mill supplies steam and electricity to annexed installations s, satisfying during this period all energy demand for a stable operation, surplus electricity delivered to Electric national System (SEN in Spanish).

In addition, with surplus bagasse recovered and crop residues (straw) from cane fields will ensure electricity generation to supply distillery and SCP plant needs during a significant period of off-season, including an electricity surplus sent to SEN.

A common agricultural practice is to remove from the field only 50% of crop residues, remaining amount maintain soil moisture, limit undesirable plants and replenish part of soil organic matter.

To carry out mass and energy balances, Daflex 2.0 Simulation Software designed in ICIDCA for analysis of Diversification Alternatives of Sugar Industry [7] was used. Assumed values for these calculations are shown in Table 1 [8,9].

Table 1: Assumed assumptions for mass and energy balances.

Parameter	Value	Unit of measurement
Sugarmill Capacity	6900	t/d
Days of harvest	150	días
Fiber in cane	13,97	%
Pol in the cane	13,04	%
Bagasse% cane	28	%
Bagasse humidity	48	%
Bagasse Pol	1,8	%
Straw% cane	25	%
Boiler capacity	100	t/h
Number of boilers	2	-
Steam pressure	42	bar
Steam temperature	400	ºC
Boiler consumption index	2,2	kg vapor/ kg bagazo
Boiler efficiency	85	%
Turbo-generator capacity	15	MW

Type of turbo- generator	Extracción - condensación	
Turbogenerator efficiency	80	%
Steam consumption in turbo-generators	7,3	kg/kW
Exhaust pressure	2,5	bar
Distillery capacity	500	Hl/d
Fermentation efficiency	80	%
Distillation efficiency	99	%
Fermentable sugars in molasses	52	%
Unicellular protein plant capacity	10	t/d
Vinasse / yeast consumption index	75	m3/t
Biomass / substrate yield	24	%
Source: Boiler and turbo generator values		

For production costs calculation following premises was considered:

- Currencies used for analysis were Cuban Convertible Peso (CUC) and total currency (MT) that is an addition of values in national currency and in CUC.
- Raw materials under study were based on consumption rates previously established in cost sheets prepared by Cuban Sugar Consortium (AZCUBA) Business Group in 2016.
- Prices of supplies acquired nationally or imported, were taken from base prices established by AZCUBA in 2016.
- Production cost items are defined as follows: raw materials and auxiliarymaterials, energy, general services, direct and indirect labor, indirect materials and commercial and financial expenses and taxes.

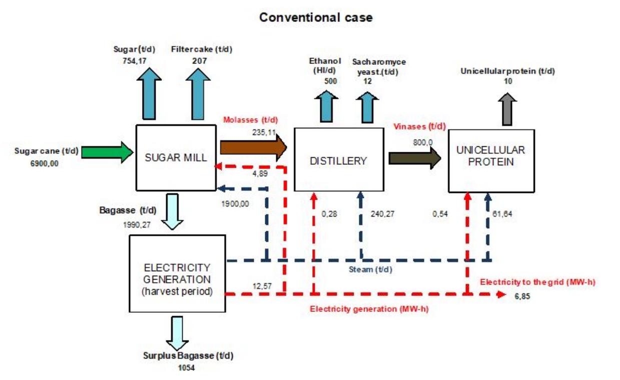

Figure 1: Block diagram of sugar mil - ethanol distillery–SCP plant integration as conventional case.

RESULTS

Conventional case

Results obtained for Conventional Case are shown in Figure 1. Sugar mill produces 754 t/d of sugar for sale and 207 t/d of filter cake that can be used as fertilizer in sugarcane fields directly or for compost production.

Of molasses produced (235 t/d), 187 t/d will be used during milling period for bioethanol production and remaining one will be stored for ethanol production in off-season., also 12 t/d of Sacharomyce serevisiae dry yeast recovered from alcoholic fermentation with high protein content for animal feed, is obtained as an additional product.

From cane milled bagasse represents just over 28% by weight and it is used for cogeneration during harvest period. As it is shown, steam and electricity generated satisfy energy demands of all plants of complex, delivering 6,85 MW-h of surplus electricity to SEN From this balance, 1054 t/d of surplus bagasse and 863 t/d of straw, are recovered during milling season to be used in cogeneration during off-season-period (Inactive Period Case).

Off-Season Period

Use of surplus bagasse and crop residues (straw) for cogeneration in inactive sugar production period is an attractive and efficient method of producing thermal and electrical energy to supply distillery and SCP plant that will operate around 270 days/ year.

From environmental point of view, use of these residual guaranties operation without use of fossil fuel, thus reducing production costs and emission levels, as well as increasing an additional income due to efficiency increases and sale of surplus electricity.

Straw generated during cane harvesting is normally used to replenish carbon, slow down undesirable plants emergence in cane fields and preserve soil moisture, because of these only 30-50% of total amount can be used as fuel in sugar mill a careful practice frequently forgotten.

Having that low calorific value of one ton of bagasse (with 50 % humidity) is similar to 0,213 tons of fuel oil, as stated in OIA (2014) report, it is possible to consider that, surplus bagasse obtained in this complex could generates - in off-season same amount of electricity as with combustion of 31981 tons of oil, which would represent a saving of 12333471,32 USD/ year, and if considering a price of oil in international market as 60 USD//barrel. (www.preciopetroleo.net, 2018).

With this surplus bagasse amount and the straw resulting from the cane harvesting could be operated 100 days in the inactive period, in a cogeneration system, providing the heat needs of the entire complex and delivering 15 MW-h to the network (see Figure 2).

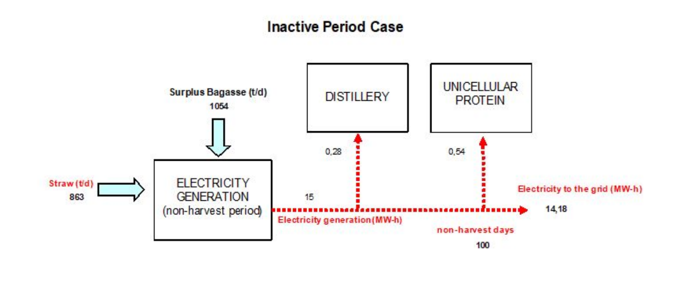

Figure 2: Block diagram of sugar mil - ethanol distillery – SCP plant integration for off-season period Case in Inactive period.

Table 2 shows production costs variation in distillery and SCP plant, when energy integration of these plants with sugar mill.

Table 2: Unitary production costs of ethanol and unicellular protein.

Plant	Distillery		Unicellular Protein	
	MT /Hl	CUC/Hl	MT/t	CUC/t
Production Cost before integration	98,81	24,78	1411,57	1069,45
Production Cost after integration	79,24	4,11	1153,22	755,46

As can be seen, costs in both currencies decrease because it is not necessary use of fossil fuel for steam and electricity generation. As electricity which comes from sugar mill has a much lower cost than when it is bout from network. Greatest decreases occur in CUC currency with 83,41% in distillery and 34,49% in SCP plant, which would imply a total saving of 3.065.385,00ºCUC in harvest season, when distillery represents 70% of contribution and SCP plant 30%.

This result shows importance of achieving integration and coherence in operation of different plants of an agro industrial complex, where they all contribute to a stable operation and greater power energy efficiency, corroborating that only sugarcane is a raw material able to provide fuel for its processing and also provide an additional margin of energy for different purposes., plus a wide range of coproducts.

CONCLUSION

- In this analyzed complex, not only steam and electricity demands of all plants involved are met, but also 6,85 MW-h of electricity are delivered to national network during harvest period
- Surplus bagasse obtained and straw resulting from sugar cane harvest, generate energy for 100 days operation of annexed plants in off-season and additionally 14 MW/-h will be delivered to national grid.
- Energy integration of sugar mill-distillery-SCP plant, contributes not only to environment protection by saving of fossil fuel, induce a reduction of emissions, and cut production costs by concept of electricity consumption.

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