COGENERATION POTENTIAL IN COLOMBIAN SUGAR MILLS

By

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Abstract

NOWADAYS, the Colombian sugar industry is involved in an expansion process, mainly related to the diversification of final products. In this way, since 2005 five ethanol distilleries are running, covering just 65% of total ethanol demand. Distilleries were designed coupled with a composting plant, based on vinasses and sludges from the sugar plant. Both distilleries and composting plants show many features which make them a special case in the ethanol market, so they produce a maximum of 3 L vinasse/L ethanol. Besides, in all cases, the thermal and electrical power requirements at the ethanol plant are supplied by the sugar plant. In this paper, a brief description of technological features of the typical process configuration followed by the Colombian sugar industry is shown. It comprises the steam consumption distribution by sections, the common configuration of the heat exchanger network (HEN) developed for vegetal steam usage and the role of the energetic self-sufficiency of the factory played by the bagasse quality. A set of possible scenarios for improving energy efficiency in a selected mill which comprises a modified HEN can be formulated, including a revamping of existing boiler and finally a new boiler operating at higher pressure. Based on the previous information, the state of the main Colombian cogeneration projects based on sugar cane and its potential impact on national energy supply is shown. Finally, the paper describes how Colombian governmental requirements for cogeneration plants are trying to establish a legal framework for this novel industrial activity in the country.

Introduction

In Colombia, the sugar sector is one of the most important thermal energy consumers. Steam % cane is an indicator of the quantity of thermal energy used in the process. This index for the Colombian sugar mills ranks between 500 and 680 kg steam/t cane. Besides, the index of electrical energy usage in the process is increasing since the ethanol plants began operation (2005), reaching values of 30 kW-h/t cane.

This paper shows how the configuration of the heat exchanger network (HEN) for different stages in the sugar mill process is useful to improve energy efficiency and to project different cogeneration configurations. Finally, as a result of this analysis, a general review of the present cogeneration projects in the sugar mills is presented, including the Equivalent Electrical Efficiency (EEE) calculated for each of them.

Methodology

First, a detailed characterisation of the production process in a selected sugar mill is required. The mass and energy balance is obtained including an evaluation of the efficiency and fuel waste in the boilers. Thus, the electrical energy generation requirement was obtained for the actual conditions.

Next, alternative cogeneration schemes for the sugar mill are projected, taking into account the implementation of new technologies for improving energy saving. After that, by applying 'Pinch Technology' in sections like heating, evaporation and concentration, the potential of saving steam is determined. Finally, for assessing the legal feasibility of several Colombian sugar mills' cogeneration projects, the Equivalent Electrical Efficiency is calculated.

Selected sugar mill characterisation

The selected sugar mill is located in the north zone of the Cauca Valley, Colombia. The total cane crushed during 2007 was 1 260 305 tonnes for 287 working days. In Table 1, a description of principal processes used in the sugar mill is presented. The energy and mass balance for the actual scenario are presented in Figure 1.

The energy incoming with bagasse is taken by the distilleries (17.8%), the turbo generators (38.9%), the process turbines (20.4%) and the remainder is lost in the boilers. The electrical power is supplied by three turbogenerators (18.5 MW in total), which are enough to supply all process requirement. Figure 2 shows the exhaust steam use distribution in the process.

Table 1—Description of main features in selected sugar mill

Section	Quantity	Description
Preparation	1	Electrical heavy shredder
Mills	6	1 Steam power drives 5 Hydraulic power drives
Boiler	2	# 1: 54446 kg/h – 22 bar – 310°C # 2: 89383 kg/h – 22 bar – 400°C
Juice heater	3	First Heater : III Effect vapour Second Heater: II Effect vapour Third Heater : I Effect vapour
Evaporation	5	Configuration of five effects

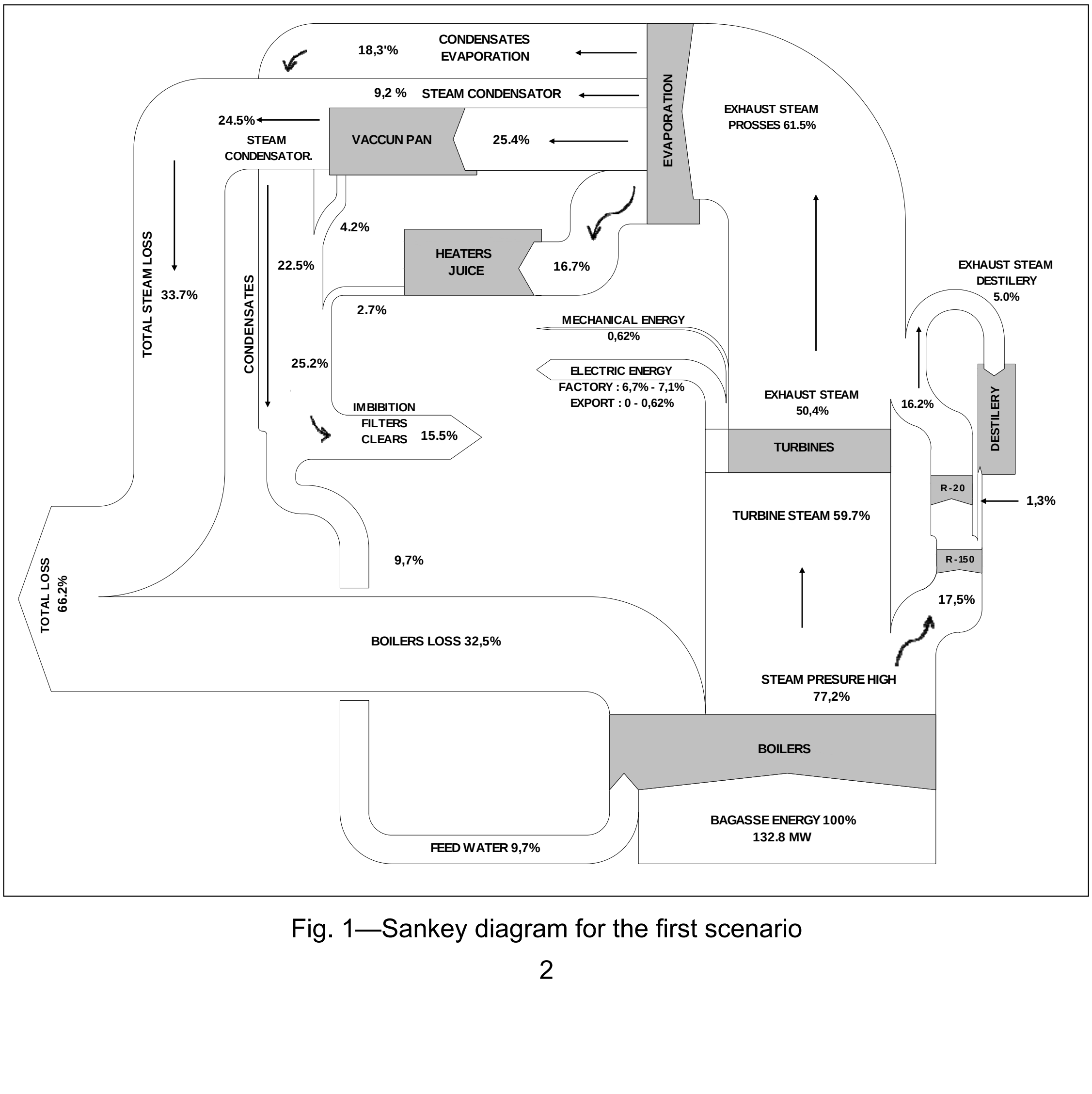

Fig. 1—Sankey diagram for the first scenario

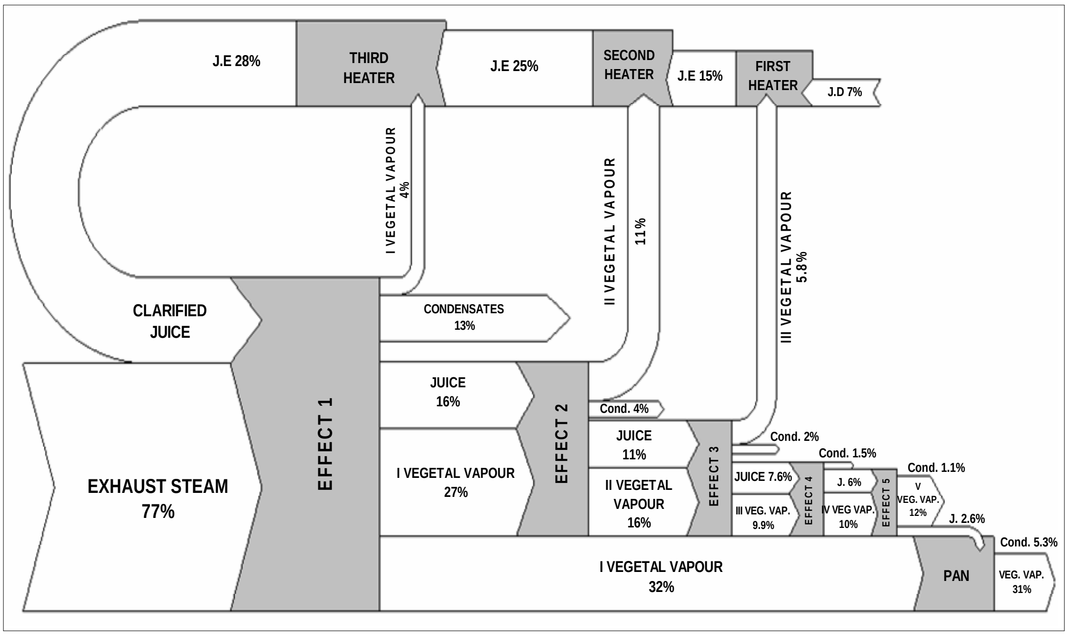

Fig. 2—Sankey diagram for exhaust steam use.

Options for improving energy use

First scenario: Applying HEN

The 'Pinch Technology' is a process designed tool which can be used in different sugar processes. So, for the selected sugar mill configuration, a new Heat Exchanger Network (HEN) would save 9 t/h exhaust steam.

In the juice heating station, a new juice heater was proposed, taking advantage of the thermodynamical quality of exhaust steam, saving around 295 kg/h of steam, by decreasing the pinch point from 12.3°C to 9°C.

The new equipment should be installed before the evaporation station. Besides, four new configurations for the juice heating station were proposed in order to save exhausted steam. In Table 2, the four alternatives are presented.

Figure 3 shows the thermal efficiency obtained by each one of these configurations. This index could be increased from 90% to 94%. The total saving in energy potential is around 9 MW.

Table 2—Possible configurations for using vapour from different effects in the juice heating station,

	Heater 1	Heater 2	Heater 3
Configuration 1	III Effect vapour	III Effect vapour	I Effect vapour
Configuration 2	III Effect vapour	II Effect vapour	II Effect vapour
Configuration 3	III Effect vapour	III Effect vapour	II Effect vapour
Configuration 4	IV Effect vapour	III Effect vapour	II Effect vapour

Second scenario

For the second scenario, increasing boiler operation pressure (from 22 bar to 40 bar) and flow of cane crushed (5% more) were considered. Electrical power motors should be installed for mills and boiler fans and the use of a continuous pan using second effect vegetal vapour from the evaporation station were also considered.

Figure 4 presents this scenario layout. The modification results in saving around 2858 kg/h of steam by the use of continuous pan, and around 1.7% (2.3 MW) from the total bagasse energy is available for selling to the grid. Figure 5 presents the results.

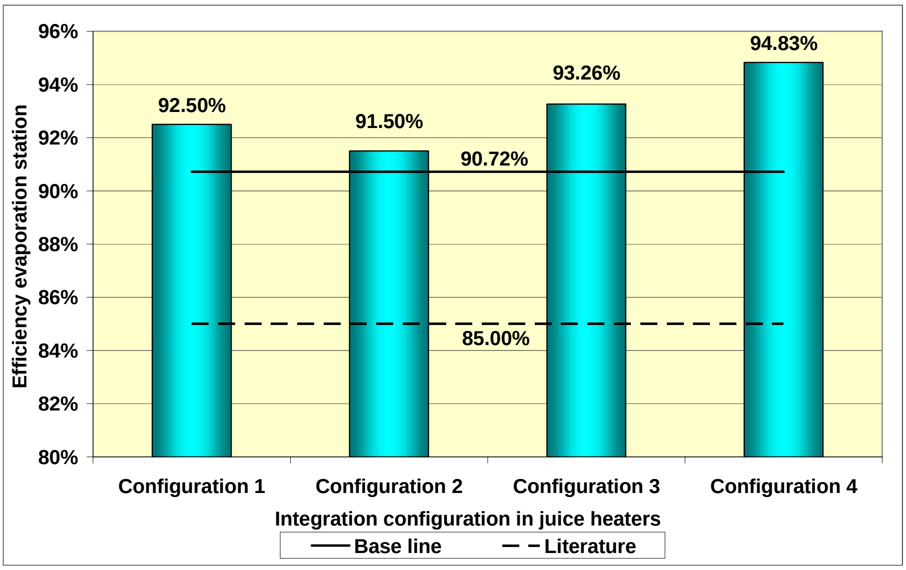

Fig. 3—Evaporation station efficiency for proposed new configurations

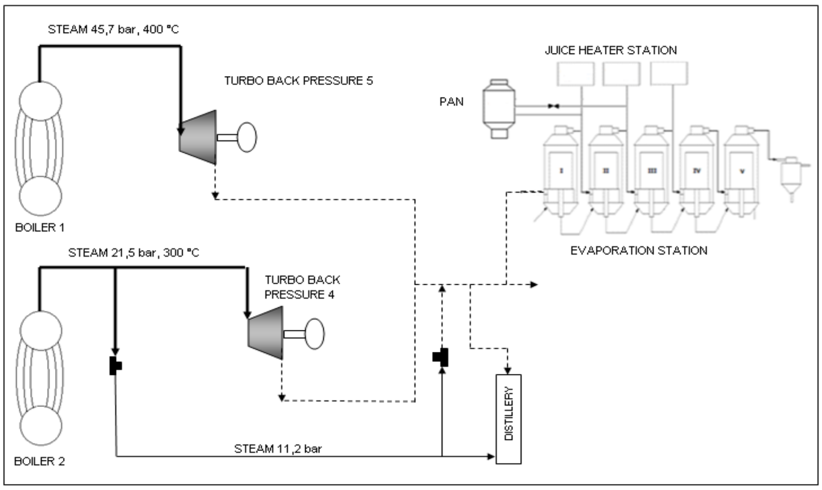

Fig. 4—Modifications in the second scenario.

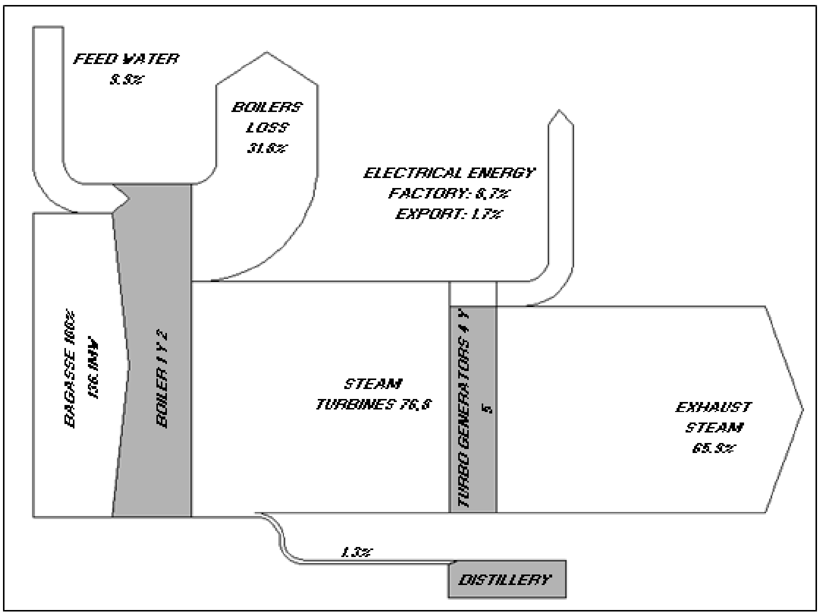

Fig. 5—Sankey diagram for the second scenario

Third scenario:

In this case, a new boiler operating at higher pressure and temperature (65 bar and 480°C) and a new, more efficient extraction–condensation turbo generator (5.4 kg steam / Kw-h) were considered. A 21.5 bar steam extraction is projected from the new turbo generator to supply the evaporation station. The modifications on electrification of mill station and boiler fans and continuous pan implementation from second scenario were conserved. Figure 6 shows this third scenario. In this case, electrical power available for selling to the grid reaches values of 11 MW. In Figure 7, the Sankey diagram about the energy distribution for this case is presented.

Comparisons between the total electrical power generated in each one of the three scenarios are presented in Figure 8.

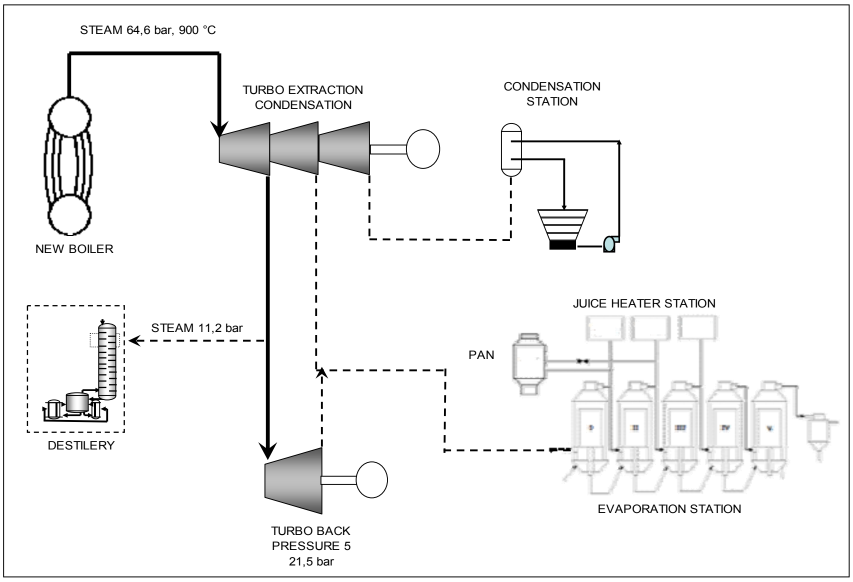

Fig. 6—Modifications in the third scenario.

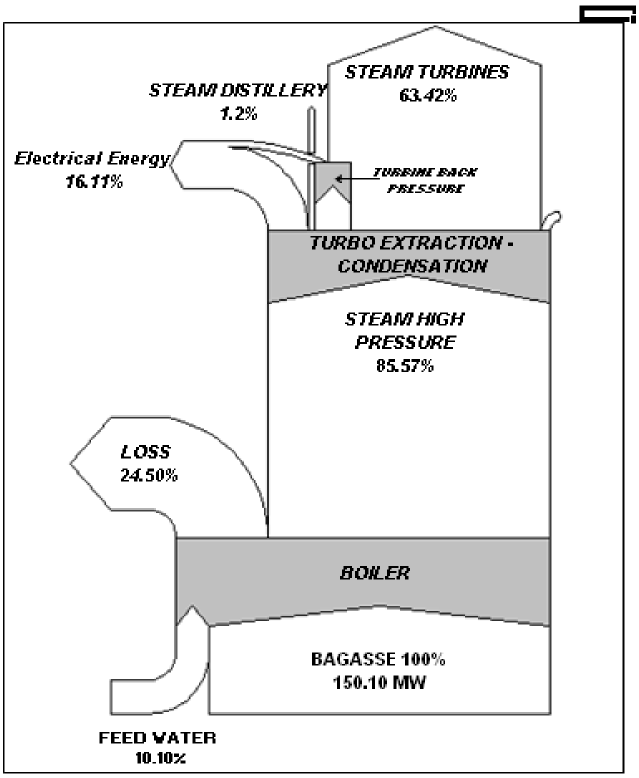

Fig. 7—Sankey diagram for the third scenario.

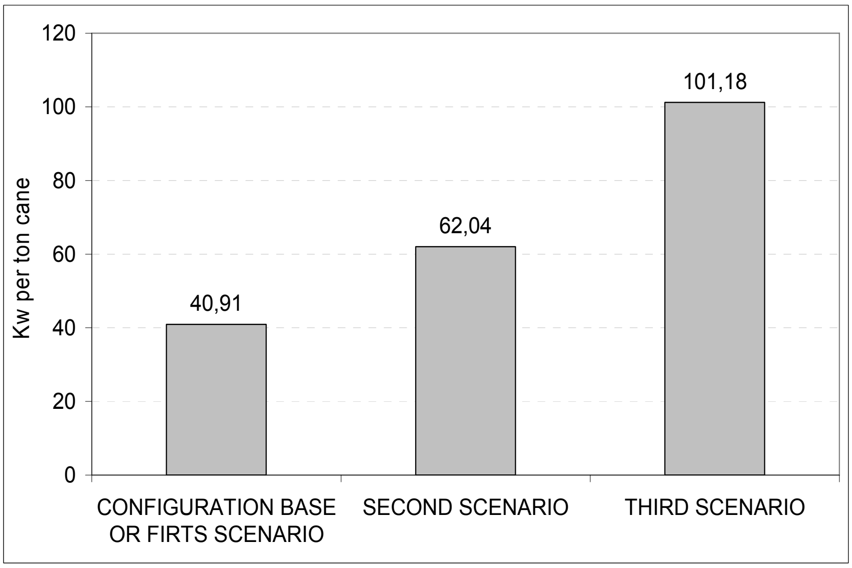

Fig. 8—Total electrical power generated.

General overview of colombian cogeneration sugar mill projects:

Actually, seven cogeneration projects in the Colombian sugar mills are in progress. Table 3 presents a review about the main features of them. The total potential electrical power generation is about 145 MW. Colombian governmental requirements for cogeneration plants are trying to establish a legal framework for this novel industrial activity in the country. For this purpose, an efficiency indicator was proposed, called Equivalent Electrical Efficiency (EEE), which can be determined as follow:

$$EEE = \frac{EE}{\left[PE - \frac{UH}{\eta_{ref}}\right]}$$

Where: EE = Electrical energy production
PE = Primary Energy consumption
UH = Useful Heat produced
η_{ref} = Reference Boiler Efficiency

Table 3—Cogeneration projects in Colombian sugar mills

	MILL # 1	MILL # 2	MILL # 3	MILL # 4	MILL # 5	MILL # 6	MILL # 7
Cane crushed (t/h)	440	300	270	370	330	580	230
Boiler (Pressure- Temp)	67 (bar) 540 (°C)	67 (bar) 505 (°C)	63 (bar) 510 (°C)	62 (bar) 480 (°C)	62 (bar) 480 (°C)	45 (bar) 395 (°C)	64 (bar) 500 (°C)
Turbo generator BP: Back-pressure EC : Extraction - condensation	BP (20 MW) EC (20 MW)	BP (27 MW) EC (10 MW)	BP (25 MW)	BP (20 MW) EC (20 MW)	BP (20 MW) EC (18 MW)	EC (35 MW)	BP (10 MW) EC (10 MW)
Fuel	Bagasse - Carbon	Bagasse - Carbon	Bagasse - Carbon	Bagasse - Carbon	Bagasse - Carbon	Bagasse - Carbon - Trash	Bagasse
Power to sell	20 (MW)	25 (MW)	12 (MW)	21 (MW)	23 (MW)	10,5 (MW)	10 (MW)
EEE - η Ref: 90%	23.0%	25.4%	27.9%	22.6%	22.8%	22.2%	23.2%
EEE - η Ref: 70%	33.4%	37.1%	38.4%	33.6%	33.8%	35.3%	34.0%

So, it is proposed that a minimum value of 30% for EEE in cogeneration projects based on sugar biomass is required. For calculating EEE in any cogeneration project, reference efficiency for transformation of chemical energy of the fuel to thermal energy is necessary. The Colombian government established 90% as a reference efficiency, but boilers using biomass fuel can just reach 70% on average. Figure 9 shows the EEE for a typical sugar mill cogeneration project calculated with 90% and 70% of reference efficiency. Predetermined EEE value of 30% is just reached using 70% of reference efficiency only.

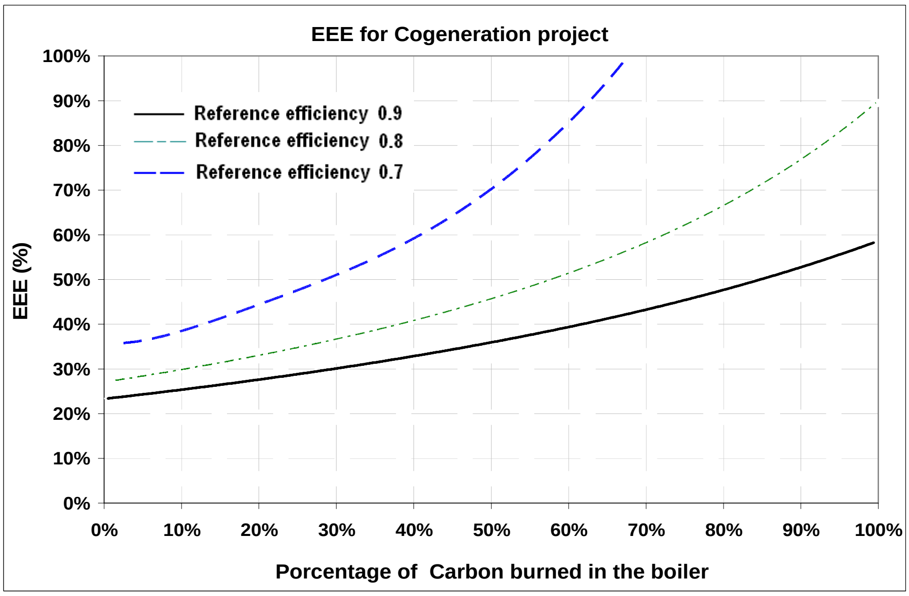

Fig. 9—EEE vs. fuel quality relationship.

Conclusions

Cogeneration is a reality for the Colombian sugar industry with seven projects, accounting for a potential sale of electric power of 145 MW, which gives it a more energetic and technological support to the sector. Planning of a cogeneration project must evaluate different scenarios, including those which involve the energy balances of the process, for determining the real potential for cogeneration. This is a vital part of the assessment of project´s feasibility. A draft of the cogeneration of steam at high temperature and high pressure will give a better chance to get the thermal energy for conversion into electricity. The use of comparative indexes for regulating cogeneration projects (as EEE in Colombian national rules) should be done in consideration of the particular conditions of the technology in use, such as in the case of bagasse boilers.

POTENTIEL DE COGÉNÉRATION DANS LES SUCRERIES DE COLOMBIE

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MOTS CLÉS:Cogénération, Colombie, Distillation, l'Électricité, Éthanol, Vapeur, le Sucre.

Résumé

DE NOS JOURS, l'industrie sucrière colombienne est impliquée dans un processus d'extension, principalement lié à la diversification des produits. De cette façon, depuis 2005 cinq distilleries d’éthanol sont en fonctionnement et couvrent 65% de la demande totale. Ces distilleries ont été conçues en couplage avec une usine de compostage utilisant la vinasse et les boues provenant de l'usine de sucre. Distilleries et usines de compostage montrent de nombreuses fonctionnalités qui les rendent particulières sur le marché de l'éthanol car elles produisent un maximum de 3 L vinasse L^{-1} d'éthanol. En outre, l'alimentation électrique et thermique de la distillerie est fournie par les sucreries. Dans cette communication, une brève description des caractéristiques technologiques de la configuration de processus typiques de l'industrie sucrière colombienne est présentée. Cela comprend la consommation et la distribution de la vapeur par sections, la configuration du réseau échangeur de chaleur (HEN) développé pour les usages végétaux et le rôle de l'autosuffisance énergétique de l'usine assurée par la qualité de la bagasse. Un ensemble de scénarios pour améliorer l'efficacité énergétique dans une usine donnée comprend une HEN modifiée peut être formulé, y compris une réorganisation des chaudières existantes et enfin, une nouvelle chaudière fonctionnant à pression plus élevée. D'après les informations anterieures, l'état des principaux projets colombiens de cogénération à partir de la canne à sucre et son impact potentiel sur la fourniture énergétique nationale est présenté. Enfin, cette communication décrit comment le gouvernement colombien tente d'établir un cadre juridique pour cette nouvelle activité industrielle dans le pays.

POTENCIAL DE COGENERACIÓN EN INGENIOS ZUCAREROS COLOMBIANOS

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PALABRAS CLAVE: Cogeneración, Colombia, Destilación, Electricidad, Etanol, Vapor, Azúcar.

Resumen

EN LA ACTUALIDAD la industria azucarera colombiana está envuelta en un proceso de expansión, principalmente de diversificación de los productos finales. Así, desde el 2005 operan cinco (5) destilerías de etanol, que cubren solamente el 65% de la demanda total de etanol. Las destilerías fueron diseñadas acopladas a plantas de 'compost', basadas en vinazas y lodos residuales de las plantas de azúcar. Ambas, las destilerías y las plantas de 'compost', muestran muchos rasgos que las hacen un caso especial en el mercado de etanol, producen un máximo de 3L de vinazas/L de etanol. Además, en todos los casos, los requerimientos térmicos y de energía eléctrica de la planta de etanol se suministran por la planta de azúcar. En este trabajo se muestra una breve descripción de los rasgos tecnológicos de una configuración típica del proceso seguido por la industria azucarera colombiana. Esto comprende la distribución del consumo de vapor por secciones, la configuración común de la red de intercambiadores de calor (HEN), que se desarrolló para el empleo del vapor vegetal y el papel de la autosuficiencia energética que juega la calidad del bagazo... Se puede formar un juego de escenarios para incrementar la eficiencia energética en un Central seleccionado, que comprende un HEN modificado, incluyendo una reconstrucción de las calderas existentes y finalmente una caldera operando a más altas presiones... Finalmente se muestra, basándonos en la información previa, el estado de los principales proyectos colombianos de cogeneración basados en la caña de azúcar y su potencial impacto en el suministro nacional de energía. Concluyendo el trabajo con una descripción acerca del como los requerimientos gubernamentales colombianos están tratando de establecer un marco legal para esta novedosa actividad industrial en el país.