Energy xxx (2015) 1–18

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Reduction of process steam demand and water-usage through heat integration in sugar and ethanol production from sugarcane – Evaluation of different plant configurations

Eduardo A. Pina [a], Reynaldo Palacios-Bereche [a, *], Mauro F. Chavez-Rodriguez [b], Adriano V. Ensinas [a, c], Marcelo Modesto [a], Silvia A. Nebra [a, d]

[a] Centre of Engineering, Modelling and Social Sciences (CECS/UFABC), Federal University of ABC, Av. dos Estados, 5001, CEP 09210-580 Santo André, SP, Brazil
[b] Energy Planning Program, Universidade Federal do Rio de Janeiro (PPE/UFRJ), Rio de Janeiro, Brazil
[c] École Polytechnique Fédérale de Lausanne- STI-IGM-IPESE, Station 9, 1015 Lausanne, Switzerland
[d] Interdisciplinary Centre of Energy Planning (NIPE/UNICAMP), University of Campinas, Rua Cora Coralina, 330, CEP 13083-896 Campinas, SP, Brazil

A R T I C L E I N F O

Article history:
Received 29 January 2015
Received in revised form
8 June 2015
Accepted 9 June 2015
Available online xxx

Keywords:
Ethanol
Sugar
Sugarcane
Heat integration

A B S T R A C T

The sugarcane industry represents one of the most important economic activities in Brazil producing sugar and ethanol for the internal and external markets. There are also plants dedicated only to ethanol production. The aim of this study is to accomplish a joint assessment to evaluate the reduction of process steam demand and water usage obtained through heat integration and an exergy analysis to quantify the reduction in irreversibility generation owing to heat integration procedure. Two configurations of plant were analysed Case I – all sugarcane juice is destined to produce ethanol without sugar production and Case II – distribution of 50%/50% of total recoverable sugars in sugar and ethanol production. Simulations in ASPEN PLUS® software were performed in order to evaluate the mass and energy balances and heat integration using the Pinch Method was applied in order to minimize the utilities consumption. The results showed that heat integration promoted a reduction in steam consumption of 35% approximately, while the reduction in water consumption (water collecting requirement) was 24 and 13% in comparison to the conventional cases without heat integration.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Over the recent years as energy security and environmental concerns have risen up various political agendas, there has been a substantial interest in biofuels and their potential contribution to energy security, mitigation of GHGs (greenhouse gases) in the transport sector and also in delivering rural economic development benefits. Many countries around the world have developed or are developing biofuel mandates that require specific and rising contributions within the transport sector in the following years.

World fuel ethanol production in 2012 was estimated at about 107 billion L [1], from which approximately 49% corresponded to the United States of America, the main world producer since 2006. For more than three decades (from mid-1970s to 2006) Brazil was the world's largest producer and consumer of ethanol. In 2012, the country figured in the third position, with a share of about 20% (21.11 billion litres of ethanol). According to EPE (Empresa de Pesquisas Energéticas) [2], there has been an increase of 6.3% in the national sugar production and an increase of 2.4% in the national ethanol production from 2011 to 2012.

Most of the sugarcane plants in Brazil have been projected to produce both sugar and ethanol, prioritizing one over the other according to market prices. The decision of how to distribute and prioritize ethanol and sugar productions from sugarcane will definitely affect the process water and steam demands, which could have impacts on its sustainability, for example on their water consumption or GHG emissions balances.

Sugarcane plants projects are forced to improve water management, reducing water losses, closing circuits, and take advantage of water content in the own sugarcane (average of 700 L of water in a tonne). Nowadays, in Sao Paulo State in Brazil, sugarcane-ethanol sector represents around 7% of superficial

* Corresponding author.
E-mail addresses: reynaldo.palacios@ufabc.edu.br (R. Palacios-Bereche), mfchavezr@gmail.com (M.F. Chavez-Rodriguez), adriano.ensinas@ufabc.edu.br (A.V. Ensinas), marcelo.modesto@ufabc.edu.br (M. Modesto), silvia.nebra@pq.cnpq.br (S.A. Nebra).

http://dx.doi.org/10.1016/j.energy.2015.06.054
0360-5442/© 2015 Elsevier Ltd. All rights reserved.

List of abbreviations

BIGCC	biomass integrated gasification combined cycle
CCs	composite curves
CHP	combined heat and power
EPE	Empresa de Pesquisas Energéticas
GCC	grand composite curve
GHG	greenhouse gases
H	enthalpy
LHV	low heating value
MEE	multiple effect evaporator
SMA	Secretaria do Meio Ambiente
T*	shifted temperature
TRS	total recoverable sugars

water withdrawals in the State, according to [3] it is estimated that currently the sector have an average water withdrawal of 1 m^3/t of sugarcane which have been reduced drastically when compared to 5.6 m^3/t of sugarcane in the 1990s. Legislations, approved (Resolution SMA-88, 19/12/2008) establish regional division in the State, and approve new enterprises with a top of 1 m^3/t of sugarcane in adequate regions, and only 0.7 m^3/t of sugarcane in adequate regions with environmental restrictions. Another by-product of Brazilian sugarcane plants is electricity generated by their cogeneration systems. Plants with generating capacities exceeding 28 kWh/t of processed sugarcane are usually able to offer electricity surplus for sale to the public electricity grid. Several works have demonstrated the importance of reducing the energy consumption, namely steam, in the ethanol production process [4]. Such reduction will allow more surplus bagasse to be used either in the cogeneration system for electricity production, or in the second-generation ethanol production.

Heat integration and Exergy Analysis can be a powerful tool to achieve energy consumption optimization. According to Gundersen [5], process integration methods can be featured by the use of three main tools: heuristics, about design and economy; the use of optimization techniques and thermodynamics.

Heuristics techniques use different configuration scenarios and handle qualitative knowledge. For instance Moncada et al. [6] assess different conversion pathways in a sugar cane plant as function of feedstock distribution and technologies for sugar, ethanol, electricity and by-products production. On the other hand, Ensinas et al. [7] analysed steam demand reductions on two different configuration sugar cane plants and alternatives for the cogeneration systems, aiming at the surplus electricity generation increase. For water consumption reduction, Chavez–Rodriguez et al. [8] developed an heuristic method for a sugar cane plant, in which higher quality demand is supplied by available higher quality streams, complemented as necessary by the water from the treatment plant. This method showed to be suitable for handling the available information regarding the feed stream requirements for each process.

Optimization techniques can be divided into deterministic and non-deterministic methods [5]. Process integration techniques and multi-objective optimization have started to be applied recently in the last decade for biofuel production [9]. Ensinas et al. [10] performed a thermoeconomic optimization of the evaporation system and heaters network design in a sugarcane mil. Morandin et al. [11] applied optimization techniques to assess potential ways for energy integration improvement in a first generation sugar-cane plant, first focussing on the process only and then including a CHP (combined heat and power) system fuelled with the main process by-product. Furthermore, Ensinas et al. [12] applied a multi-objective optimization technique using evolutionary algorithms, in order to provide a set of solutions for a sugarcane ethanol distillery with 1st and 2nd generation processes in the same site using sugars and bagasse as feedstock respectively. Bechara et al. [13] applied optimization techniques to a stand-alone bagasse to ethanol plant, with the objective of minimizing the process's utility consumption for a fixed ethanol production rate.

Ahmetović et al. [14] performed an optimization of energy consumption in a corn-based ethanol plant and assessed its impact in water consumption, furthermore they used nonconvex nonlinear programming to minimize the total cost of water networks (which includes water reuse, water regeneration, recycling, local recycling around process) consisting of the cost of freshwater, the investment cost of treatment units, and the operating cost for the treatment units. Martín et al., [15], using similar methodology from Ref. [14] addressed water consumption optimization of second generation bioethanol production plants from lignocellulosic switch grass.

Finally, techniques such as Pinch Point [16] and Exergy Analysis focus on thermodynamics aspects of the process. Exergy studies on sugar cane plants started first than Pinch Analysis. Ensinas et al.'s [17] exergetic analysis shows that the highest contribution for the total irreversibility generation in a conventional sugarcane plant in Brazil were made by co-generation, juice extraction and fermentation systems. Modesto et al. [18], through an exergetic cost approach in a distillery of sugarcane showed the reduction of thermal energy consumption achieved by the insertion of diffusers as juice extraction technology. The combined production of sugar, ethanol and electricity for different configurations of the cogeneration plant has been analysed by Pellegrini et al. [19] and Pellegrini and de Oliveira Jr. [20] using exergy-based costs. The lowest exergy-cost is achieved by pressurized BIGCC (biomass integrated gasification combined cycles) compared with atmospheric BIGCC, super critical steam cycles, and traditional mills. Sosa-Arnao and Nebra [21], focused exergetic analysis on bagasse boilers in order to identify improvement opportunities. Palacios–Bereche et al. [22] conducted an assessment of the exergy and exergetic cost associated with the ethanol production process from sugarcane biomass, including the route of bagasse enzymatic hydrolysis.

One of the first Pinch Point studies for the sugarcane industry in academic literature was made by Dias et al. [23] for an autonomous distillery, furthermore in Dias et al. [4] a similar analysis was made including different cogeneration configurations. On the other hand, Morandin et al.'s [11] Pinch analysis was applied for a joint production of sugar and ethanol. Palacios–Bereche et al. [24] extended the Pinch Analysis for ethanol production by enzymatic hydrolysis.

For a sugarcane distillery, Palacios–Bereche et al. [25] applied heat integration using Pinch Point Analysis for plant with a diffuser juice extraction system, furthermore in Palacios–Bereche et al. [26] this analysis was made considering mechanical vapour recompression integrated to the juice evaporation system. Pina et al. [27] also accomplished Pinch Analysis to an autonomous distillery and a sugar and ethanol plant evaluating the thermal demands and surplus electricity in each case while Martinez–Hernandez et al. [28] applied the Pinch Analysis, including Mass Pinch, to the ethanol production process from wheat. Finally, Albarelli et al. [29] performed a Pinch Point Analysis for a sugarcane plant integrated with a second generation process that used bagasse as feedstock; water demand reductions by heat integration were also quantified in Ref. [29].

Please cite this article in press as: Pina EA, et al., Reduction of process steam demand and water-usage through heat integration in sugar and ethanol production from sugarcane – Evaluation of different plant configurations, Energy (2015), http://dx.doi.org/10.1016/j.energy.2015.06.054

Download English Version:

https://daneshyari.com/en/article/8072739

Download Persian Version:

https://daneshyari.com/article/8072739

Daneshyari.com