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Review

Energy efficiency and greenhouse gas emission reduction potentials in sugar production processes in Thailand

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ABSTRACT

Sugarcane is one of the most promising sources of green energy for a major sugar producing country like Thailand. Any efforts to improve energy efficiency in sugar industry would result for green energy production and more avoided GHG emissions. This paper assesses the potentials for energy saving and GHG emission reduction in sugar production in Thailand. It is found that there is a wide gap between the most efficient mills and the less efficient ones among the country's 47 mills, with specific steam consumption ranging from 400 to 646 kg steam/ton cane. Thus significant potential exists for energy saving and GHG emission reduction in many mills, using some of the 17 commonly common technologies/measures identified. For the nine mills studied, which could have resulted in a combined saving savings of 23–32% of the total mill energy consumption, further savings of 5–14% could be achieved.

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Introduction

The industrial sector in Thailand is the largest energy-consuming sector with a share of 36% of total final energy consumption in 2012 (DEDE, 2012). Although there have been numerous efforts in improving energy efficiency in this sector over the years, well-structured approaches for specific industry types based on energy-saving potential analysis of process-specific technologies are lacking (Hasanbeigi et al., 2010). Since Thailand is the world's fourth largest sugar producer and the second largest sugar exporter after Brazil, producing annually about 95 Mt and 9.5 Mt of sugarcane and sugar respectively (OCSB,

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2012; Gudoshnikov et al., 2010), energy efficiency improvements in this sector can have a significant positive impact on both the Thai economy and the environment. Currently there are 47 sugar mills distributed throughout Thailand and the growth of sugarcane production is expected to reach more than 100 Mt of cane in 2012 (OCSB, 2012). These days sugar mills do not only produce sugar but also supply green electricity to the grid (PDTI, 2011; Ram and Banerjee, 2003; Nguyen et al., 2009). In fact the Thai sugar industry is already supplying approximately 610 MW of electricity to the grid using bagasse as fuel and generating a large amount of steam for its own use in the mills (PDTI, 2011). However the average export of electricity is only 14 kWh/tc (ton cane) as compared to 70 kWh/tc (Siemers, 2009) and 100 kWh/tc in more efficient mills in Thailand and in Brazil respectively (Isaias et al., 2008). In the Thai sugar production process, although the average specific steam consumption of about 369 kWh/tc (OCSB, 2010) is very close to the international average of 363 kWh/tc (Bocci et al., 2009), it is considerably higher than the specific consumption of 286 kWh/tc in high-efficiency mills in Thailand (JGSEE, 2011). Therefore there is much room for energy efficiency improvement in this sector, which will result in more bagasse available for energy production and additional economic benefit to the sugar millers, particularly from selling surplus electricity to the grid. Since the generation of electricity from bagasse emits only 26 kg of CO_2e per MWh as compared to 621 kg of CO_2e per MWh from fossil fuels in the Thai context (Siemers, 2009), energy efficiency improvement in sugar production will result in significant CO_2e savings as well.

However open literature on energy efficiency and greenhouse gas (GHG) emission in sugar mills is scarce. Among the few reports that are available, only major forms of energy efficiency measures are reported (see Sattari et al. (2007) for example). A systematic study to determine the potentials and approaches for energy saving and GHG emission reduction in Thai sugar mills has thus been initiated by the authors, with an aim to identify best practices and provide policy recommendations for the removal of barriers to implementing energy saving technologies and measures. In this paper, we analyze the potentials for energy saving and GHG emission reduction by investigating the energy consumption patterns and the energy efficiency technologies and measures that could potentially be applied in the sugar production processes.

Methodology

The study begins with the collection of baseline steam and electricity consumption data for selected sugar mills; an estimation of the GHG emissions associated to sugar production; identification of currently available energy efficiency improvement technologies/measures and their potentials; and assessment of the extent to which these technologies and measures have been applied in Thai sugar mills.

Collecting baseline energy consumption data

Thai sugar mills can be categorized into three production capacity ranges: i) Small (less than 10,000 tc/d or tonnes of cane per day), ii) medium (10,000 to 20,000 tc/d) and iii) large (more than 20,000 tc/d), each contributing about 41%, 42% and 17%, respectively, of the total sugar production capacity (OCSB, 2007). In this study, field surveys are to be carried out to collect the baseline data of nine mills from their daily production report and estimated electric and steam consumption in each process. The nine mills, with a combined capacity of 55% of the country's total capacity (OCSB, 2007), are categorized into three groups, each consisting of three mills, representing production capacities of 22%, 15% and 18% within the small, medium and large categories mentioned above. One sugar mill from each category, i.e. mills A, B and C, who has provided the most complete data set required for the analysis, is then selected for detailed analysis. The capacities of mills A, B and C are 9480; 12,000 and 32,160 tc/d, respectively.

Estimating the baseline CO_2e emission

Since bagasse is practically the only source of energy in the sugar mill production process in Thai sugar mills, the associated GHG emissions are estimated from the burning of bagasse only. According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, during biomass combustion carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are released. Since CO_2 emissions from bagasse burning are not deemed as contributing to net greenhouse gas emissions because the CO_2 emitted is re-absorbed by plants in the next cultivation season, this study therefore takes into account only other gases aside from CO_2 and converts them into their carbon dioxide equivalent (CO_2e). It is generally known that burning 1 TJ energy equivalent of bagasse emits about 30 kg of CH_4 and 4 kg of N_2O, (IPCC, 2006; Yuttitham et al., 2011). According to the Thai Office of Cane and Sugar Board (OCSB) report, 5 kg of bagasse burnt is sufficient to generate 10 kg of steam (20 bar 360 °C); and 10 kg of steam can produce 1 kWh of electricity. Therefore CO_2e emission from electricity and steam consumption in sugar mill processes can be estimated by using the CO_2 equivalent factor for CH_4 and N_2O, which are 25 and 298 respectively (IPCC, 2007; Yuttitham et al., 2011). The CO_2e emission in the sugar mill process is calculated from Eqs. (1)–(3) as shown in Appendix A.

Identification of energy efficiency technologies and measures

Energy efficiency technologies and measures that could potentially be applied to the Thai sugar industry are to be identified by i) reviewing the best practices that had been reported earlier by the OCSB based on the experiences of 4 sugar mills (OCSB, 2007), and ii) examining the experiences of 5 additional energy-efficient mills belonging to a large sugar production group.

Investigating the extent of energy efficiency improvement efforts

To investigate the extent to which the energy efficiency technologies and measures identified in the previous section have been implemented in both efficient and inefficient Thai sugar mills, a detailed survey is to be conducted at the 3 sugar mills (A, B and C) mentioned above, each representing a production capacity range (see Overall energy consumption of sugar mills section). A correlation will then be made between the energy performance of these mills and the number and type of technology/measure implemented.

Results and discussions

Overall energy consumption of sugar mills

Based on the overall steam and electricity consumption data and the amount of cane processed in each mill, the specific steam consumption (SSC) (kg steam/tc) and corresponding specific energy consumption of the nine selected sugar mills can be calculated. The result is plotted in Fig. 1 according to the mill capacity. From this figure, it may be inferred that the energy performance of the nine sugar mills may be roughly classified into three groups on the basis of their SSC as follows: high efficiency mills (less than 450 kg steam/tc), medium efficiency mills (between 450 and 600 kg steam/tc), and low efficiency mills (more than 600 kg steam/tc). As a consequence, 3 of the 9 mills are in the high efficiency category with SSC around 400–420 kg steam/tc, 2 are in medium efficiency category, and 4 are in the low efficiency category. A previous study (OCSB, 2007) also reported SSC for 3 other mills that fall in this range, namely 526, 533, and 630 kg steam/tc, as shown the figure (triangle). It should be noted that there is wide gap between high and low efficiency mills, with SSC ranging from 400 to 650 kg steam/tc.