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Fuel ethanol from cane molasses in Thailand: Environmental and cost performance

Thu Lan T. Nguyen, Shabbir H. Gheewala*

The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

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Abstract

In the context of the world's energy crisis and environmental concerns, crop-based ethanol has emerged as an energy alternative, the use of which can help reduce oil imports as well as emissions of CO_2 and other air pollutants. However, a clear disadvantage of ethanol is its high cost over gasoline under the current pricing scheme that does not include externalities. The intent of this study is to perform a life cycle analysis comparing environmental and cost performance of molasses-based E10 with those of CG. The results show that although E10 provides reduction in fossil energy use, petroleum use, CO_2 and NO_x emissions, its total social costs are higher than those of gasoline due to higher direct production costs and external costs for other air emissions, e.g. CH_4, N_2O, CO, SO_2, VOC and PM_{10}. An analysis of projection scenarios shows that technological innovations towards cleaner production help maximize ethanol's benefits whilst minimizing its limitations.

Keywords: Molasses-based gasohol; Environmental performance; Cost performance

1. Introduction

In those countries that are net oil importers, expectation about the net benefit of ethanol on reducing oil imports is the primary driving force behind efforts to promote its production and use. However, one of the concerns arising with an increased use of ethanol is its relatively high price over gasoline (IEA, 2004). This situation is not different for Thailand, a new market for fuel ethanol in Asia. To enhance ethanol's cost competitiveness against conventional gasoline (CG), the government's measures include excise tax exemption and fuel subsidies. In fact, market price is just only one aspect of biofuels' performance. It would not inform policy makers adequately about potential benefits of biofuels, e.g., fossil oil savings and environmental improvements upon substituting fossil-based liquid fuels in transportation. This paper aims to assess environmental and cost performance of molasses-based ethanol (MoE) in Thailand, using a life cycle approach. Life cycle fossil energy use, air emissions and cost of MoE are the three parameters to be addressed. The cost estimate includes not only the direct production/distribution costs but also the external environmental costs.

2. Methodology

2.1. Goal and scope definition

The objective of this study is to perform a life cycle analysis of environmental and cost performance of molasses-based gasohol E10 as an alternative transportation fuel in Thailand, in comparison with CG. The following parameters have been considered in the analysis.

1. Energy use (MJ energy carrier) specified as fossil energy use and fossil oil (petroleum) use;
2. Emissions of CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC and PM_{10} (particulate matter $\leqslant 10\,\mu m$ in size);
3. Total social costs, i.e. the total of private (production/distribution) costs and external costs (Maxwell School-Syracuse University, 2007).

*Corresponding author. Tel.: +66 2 4708309/10; fax: +66 2 8729805.
E-mail address: shabbir_g@jgsee.kmutt.ac.th (S.H. Gheewala).

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The functional unit chosen to compare the life cycle fossil energy and environmental performance of E10 and CG is the distance travelled by vehicles' fuel tank full of CG. The PTT Research and Technology Institute, Thailand, has conducted tests for various cars running on CG and E10 (Tantithumpoosit, 2004). The test results based on Toyota 1.6 L/2000 are used in this study. The average fuel economy of this car running on CG and E10 is 13.46 and 13.31 km/L, respectively. As acknowledged in many published works/technical reports (Brekke, 2005; Macedo et al., 2004; Fu et al., 2003), the lower heating value of ethanol is compensated by its higher combustion efficiency resulting in negligible difference in fuel economy between low-level ethanol blends and CG. A comparison between the two fuel economy values show that about 50.6 L of E10 is required to cover the same distance (673 km) travelled with a 50 L tank full of CG.

2.2. *Molasses-based ethanol fuel production in Thailand*

Regarding supply potentials, from the total national molasses production of about 3 million tonnes (Mt) a year, the surplus 30–35% is potentially available for the production of 0.8 million litres (ML) ethanol a day (Sriroth et al., 2003). Compared to cassava, which is another feedstock source for ethanol production, molasses has lower potentials but is the main supply feeding ethanol plants in Thailand currently. Out of the total capacity of 955,000 L a day registered by 7 ethanol suppliers as of April 2007, MoE accounts for up to 86% (Preechajarn et al., 2007).

2.2.1. *System boundary and data sources*

The life cycle inventory (LCI) of MoE production in Thailand has been conducted by Nguyen et al. (2007a). With the government's biofuel policy, ethanol is being distributed to consumers in the form of gasohol E10, a mixture of 10% ethanol in gasoline. Fig. 1 presents all processes and sub-processes included in the system boundary of the molasses-based gasohol. As seen, the main processes are sugarcane production, sugar/molasses production, ethanol conversion, transportation/distribution and fuel combustion in vehicles. Sub-processes involved in the system are agrochemical manufacturing, life style support for human labour, crude oil extraction/refining and coal mining/refining. Also presented in the figure is the basic information about important inputs/outputs associated with the production/processing of 1 tonne cane stalks. Brief explanations are outlined below.

- To favour crop growth, sugarcane farmers in Thailand apply different amounts of fertilizer with different formulas, which results in a higher rate of N input than P and K. The two most common herbicides used are atrazine and ametryne.
- Diesel is used primarily to fuel tractors for land preparation, partially for planting, crop maintenance and harvesting/loading in sugarcane farming. It is the sole fuel used for transportation. Diesel consumption for all transport activities is calculated based on a round-trip travel distance.
- Human labour input is needed in almost every step in sugarcane farming. It is of importance to examine how efficient a crop-based fuel production system is in terms of energy, i.e., whether more energy is produced than is consumed. Such evaluation and further comparison with other countries with different levels of mechanization require inclusion of human labour.
- The solar energy captured and stored in the biomass, considered free, was not counted. However, it should be

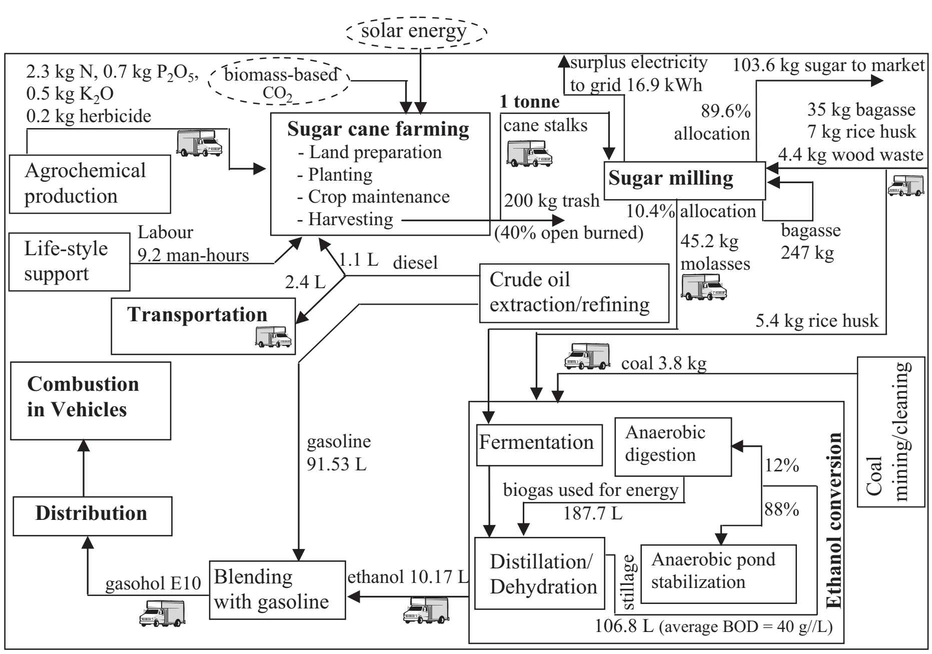

Fig. 1. System boundary for the base case of molasses-based gasohol life cycle.