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Net energy balance of molasses based ethanol: The case of Nepal

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ABSTRACT

This paper evaluates life cycle energy analysis of molasses based ethanol (MOE) in Nepal. Net energy value (NEV), net renewable energy value (NREV) and energy yield ratio are used to evaluate the energy balance of MOE in Nepal. Total energy requirements in sugarcane farming, cane milling and ethanol conversion processes are estimated and energy allocation is made between co-products (molasses and sugar) as per their market prices. The result shows negative NEV (−13.05 MJ/L), positive NREV (18.36 MJ/L) and energy yield ratio (7.47). The higher positive value of NREV and energy yield ratio reveal that a low amount of fossil fuels are required to produce 1 L of MOE. However, negative NEV reveals that the total energy consumption (both fossil and renewables) to produce the ethanol is higher than its final energy content. Nevertheless, the renewable energy contribution amounts to 91.7% of total energy requirements. The effect of the increased price of molasses and reduced energy consumption in the sugarcane milling and ethanol conversion are found to be significant in determining the energy values and yield ratio of MOE. In addition, there are clear measures that can be taken to improve efficiency along the production chain. Finally, energy security, scarcity of hard currency for importing fossil fuels and opportunities for regional development are also strong reasons for considering local renewable energy options in developing countries.

Contents

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1. Introduction

Nepal is a poor economy with only US$ 350 GDP per capita [1]. The country faces tremendous problems to secure the supply of petroleum products necessary to meet the national demand for the transport, residential and industrial sectors. NOC (Nepal Oil Corporation) is the state owned venture responsible for oil imports and the only supplier of oil products in the market. According to NOC, 752,446 m^3 of petroleum products (diesel: 39.8% and gasoline: 13.1%) were imported from India in 2006/2007, mainly to meet transport needs. The number of vehicles in the country is increasing at an average rate of 13.5% per year since 1990/1991, and more than 56% of the vehicles are registered in the Kathmandu Valley, the capital city of Nepal [2].

Energy security for transport is a quite severe problem in Nepal. The country faces frequent shortage of transport fuels, and public protests against fuel price rises are common. NOC faces serious financial problems due to mounting debts in oil import bills. NOC is selling the petroleum products for less than it pays the Indian Oil Corporation for it, and has not always been able to meet the demand of imported fuels in the country. Though NOC rose prices of major petroleum products at rates of 9–27% in June 2008, the company was accumulating losses at the order of 1.7 billion Nepalese rupees per month [3]. Instability in oil prices and deliveries has put a large burden on the Nepalese economy, compromising the country's development.

In an effort to reduce dependence on imported fuels and enhance domestic energy security, the government of Nepal (GoN) has decided to blend 10% ethanol in the petrol. The decision was motivated by high oil prices, together with the acknowledgement of the country's capacity to produce ethanol. Nevertheless, the measure has not been implemented due to technical and economic problems. In fact, there is no ethanol blend available in the market for the transport sector in Nepal yet. Meanwhile, the government has formed a high level committee early 2008 to find ways 'to reduce the consumption of petroleum products by increasing the use of alternative energy' [4].

Nine sugar mills are operating in Nepal with total installed capacity of 17,050 tonnes of cane processing per day. Sugar mills are well established and contributing to the national economy, and they have an enormous potential to produce ethanol from their by-product, molasses. Among the sugar mills, Sri Ram Sugar Mills Ltd. (SRSM) has installed a 30 m^3/day molasses based ethanol (MOE) plant to produce ethanol for transport, but the plant is not operational.

The use of bioethanol as transport fuel is growing fast following on Brazilian positive experiences and, more recently, US policies. Ethanol sources may vary from country to country. In the US, corn is being used. Developing countries like Thailand and India are producing ethanol using the sugar industries' by-product, so-called molasses based ethanol. This contrasts with the Brazilian ethanol that is usually produced in parallel with sugar or in specialized ethanol plants. In any case, ethanol has recently been subject to a lot of scrutiny mainly in the fuel versus food debate [5]. The energy balance of ethanol has also been questioned. For that matter, a number of studies have been done in various countries to verify the energy balance of the ethanol being produced and the real potential for climate change mitigation. In this study, we assess the contribution of Nepalese molasses based ethanol verifying the net energy value/balance (NEV or NEB) of the ethanol nationally produced.

NEV evaluates net energy (surplus or deficit) after deducting energy inputs in the production phase from the energy content of the derived product, in this case ethanol. It measures whether the alternative fuel option is attractive from an energetic point of view. Roughly speaking, a positive net energy value provides motivation to opt for the new fuels while a negative value does not. A number of analyses on life cycle assessment (LCA) of the net energy balance for various crops/feedstocks derived bioethanol have been studied. For example, Nguyen et al. performed the full chain energy analysis of fuel ethanol from cassava and cane molasses in Thailand [6,7]. Dai et al. estimated energy efficiency in NEV and net renewable energy value (NREV) of cassava ethanol in China [8]. Shapouri et al. reported the output/input energy ratio (energy yield) of corn ethanol in the US [9]. Rosenschein et al. evaluated energy analysis of ethanol production from sugarcane in Zimbabwe [10]. Macedo et al. calculated the net energy for sugarcane ethanol in Brazil [11]. Prakash et al. examined the energy yield for molasses based ethanol in the case of India, considering the molasses to ethanol production phase only [12].

This study deals with the net energy input/output analysis of molasses based ethanol production in the life cycle perspective in the case of Nepal. It is the first study of its kind in the Nepalese context. The goal is to estimate the net energy value of ethanol from sugar mill's by-product molasses by assessing life cycle energy/material inputs. The study is based on field study information from a sugar industry, Sri Ram Sugar Mills Ltd., in Nepal and its neighbouring sugarcane farms. The study provides useful information to policy makers, investors and individuals to judge the worthiness of policies for alternative transport fuel in Nepal as the country seeks fuel options to meet energy demand and security, and promote sustainable development.

2. Methodology

2.1. Scope of the study and system boundary

The study considers the entire life cycle energy inputs inventory (both fossil and renewables) from sugar cane farming (human labour, irrigation, and chemicals), transportation, sugar cane milling, fermentation and distillation and, finally, dehydration to produce anhydrous ethanol (EtOH, 99.5% (v/v) ethanol) (see Fig. 1). Sugarcane crops absorb solar energy but it is widely available and a common good, so solar energy inputs are not considered in the analysis. The data used have been collected in the field or correspond to energy values derived for Nepal's local conditions according to international practices.

There are two main by-products in the sugar milling process: molasses and bagasse. Bagasse is used as the fuel input to boilers. Bagasse fired boiler's steam is used in power turbines to generate electricity, and the exhaust steam is utilized in the process heating required for sugarcane milling, distillation and dehydration. Molasses are converted into anhydrous ethanol fuel (EtOH) from the route of hydrous ethanol (95% (v/v) ethanol, called rectified spirit). Fermentation and subsequent repeated distillation processes of molasses generate rectified spirit. Distillery waste water effluent (spent wash) is to be treated prior to disposal since treatment is essential from the environmental point of view. Anaerobic effluent treatment plant generates biogas, which is later used as a fuel input to the boilers. Bagasse, which is used to generate steam for the electricity and the process heat, is considered as a renewable energy input into the system. Sugarcane trash, which also has significant energy content, is not considered in the analysis as open burning before harvesting is a common practice in Nepal. Energy incurred to produce machineries/equipment, industrial installations and oil/lubrication in the factory is also not taken into account in this study.

2.2. Definition of NEV, NREV and energy yield ratio

The NEV of anhydrous ethanol (EtOH) is the difference between the energy content of the ethanol produced and the total primary