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Critical analysis of techno-economic estimates for the production cost of lignocellulosic bio-ethanol

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ABSTRACT

Bio-ethanol has been claimed to be a green and sustainable alternative to gasoline. The use of food crops on a large scale is ethically unacceptable, but lignocellulosic ethanol has potential to become an alternativfe transportation fuel. This relates to technical issues, and to the eventual cost of bio-ethanol, which requires determination of an absolute production cost. The minimum ethanol selling price (MESP) estimated in different studies varies between \$234 and \$1210 per m³ ethanol (\$0.89 and \$4.58 per gallon), although often the same processing methods are assumed. This entails uncertainties about the potential of bio-ethanol from lignocellulosic sources.

In this study, the main key factors determining these deviations are pinpointed. The assumed values in the different studies were critically investigated and more accurate, unambiguous values proposed. By doing this, a current production cost of \$651 per m³ ethanol was calculated and a realistic projection towards the near future estimates an MESP of \$511. Corn ethanol has already a higher price than the current price of lignocellulosic ethanol due to the high cost of corn. A comparison with gasoline yields a 10% lower price than the future MESP of lignocellulosic ethanol. Due to rising gasoline prices, lignocellulosic ethanol is likely to become in the future not only a more ecological but also a more economical attractive transportation fuel.

Contents

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1. Introduction

Concerns about rapidly increasing oil prices, global warming, depletion of fossil fuels and security of energy supply have stimulated interest in more sustainable energy sources [1]. The combustion of fossil fuels is responsible for more than 70% of the carbon dioxide production [2,3] The transport sector has a major contribution in greenhouse gas (GHG) emissions, of which the impact will continue to increase in the future [4,5]. According to Goldemberg [6], motor vehicles account for 19% of global carbon dioxide (CO_2) emissions [7]. Hence, reducing emissions in this sector would significantly help in reaching targets on climate change. Bio-ethanol, or ethanol derived from biomass, has been recognized as a potential alternative to petroleum based transportation fossil fuels [8]. Furthermore, it is by far the most widely used biofuel for transportation worldwide [9]. Worldwide, countries have become gradually more interested in developing and expanding their biofuel market. As a consequence, the annual world fuel bio-ethanol production has increased remarkably over the last few years from 49 billion (10^9) liters (~13 billion gallons) in 2007 to about 110 billion liters (~29 billion gallons) in 2011 [10].

Even though first generation ethanol has managed to offset some of the gasoline consumption, it has been increasingly criticized. The main reasons are the competition with the food industry and the limited GHG emission savings in comparison to fossil fuels [9,11–13]. Lignocellulosic biomass has been found to be the most promising feedstock for fermentation processes, due to its availability, low cost and the absence of competition with food production [14].

It was found that wordwide, 1623 Tg (10^{12} g) of waste crops and lignocellulosic biomass are potentially available for bio-ethanol production. From these materials, about 491 billion liters of bio-ethanol might be produced, which is about 16 times higher than the current world ethanol production (31 billion liters) [14]. Kim and Dale (2004) studied the global potential bio-ethanol production from lignocellulosic biomass and found that bio-ethanol could replace 353 billion liters of gasoline, which is equivalent to 32% of the global gasoline worldwide consumption, when used in E85 fuel (85% ethanol and 15% gasoline) for a midsized passenger vehicle [2]. Moreover, GHG reductions are projected in the range of 70–85% [15].

Lignocellulosic biomass production is technologically feasible and being tested on a demonstration-scale in many countries including the United States, Spain, Italy, Denmark and Germany [16]. Despite the large amount of research that has been carried out in this field, the economic picture of commercial large-scale lignocellulosic bio-ethanol production still remains uncertain. Therefore many techno-economic models have been developed with the aim of (1) comparing process designs, (2) evaluating the potential of research developments to reduce the production cost, and (3) determining an absolute cost to of lignocellulosic ethanol [17–34]. However, results of these techno-economic models vary significantly from one another, as presented in Fig. 1, where the

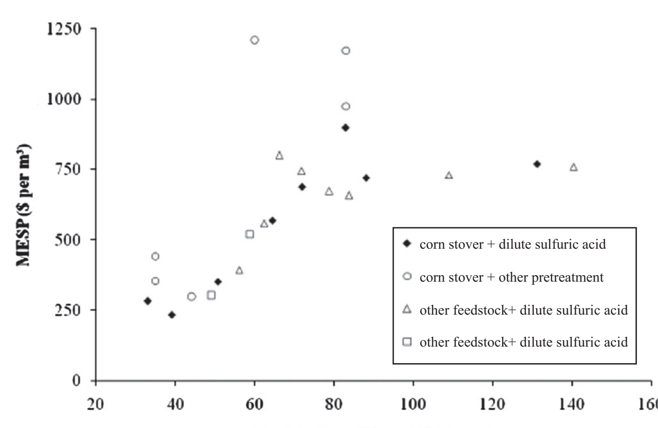

Fig. 1. General comparison of different techno-economic studies: feedstock cost vs. MESP.