



ELSEVIER

Contents lists available at SciVerse ScienceDirect

# Renewable and Sustainable Energy Reviews

journal homepage: [www.elsevier.com/locate/rser](http://www.elsevier.com/locate/rser)

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



Simon Chovau, David Degrauwe, Bart Van der Bruggen\*

Department of Chemical Engineering, Laboratory of Applied Physical Chemistry and Environmental Technology, KU Leuven, W. de Croijlaan 46, B-3001 Leuven, Belgium

### ARTICLE INFO

#### Article history:

Received 4 April 2012

Received in revised form

22 May 2013

Accepted 26 May 2013

#### Keywords:

Lignocellulosic ethanol

Techno-economics

Corn stover

Target costing

### 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 alternative 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 m<sup>3</sup> 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 m<sup>3</sup> ethanol was calculated and a realistic projection towards the near future estimates a 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.

© 2013 Elsevier Ltd. All rights reserved.

### Contents

1. Introduction	308
1.1. A side note on units and currencies	309
2. Techno-economic models	309
2.1. Processing methods	309
2.1.1. Feedstock preparation	309
2.1.2. Pretreatment or first stage hydrolysis	309
2.1.3. Second stage hydrolysis	309
2.1.4. Fermentation	309
2.1.5. Purification	310
2.1.6. Steam and electricity generation	310
2.1.7. Process integration	310
2.2. Cash flow analysis	310
2.2.1. Total capital investment	310
2.2.2. Variable and fixed operation costs	310
2.2.3. Commercial plant vs. pioneer plant	311
3. Comparison of cost estimations of techno-economic research studies	311
3.1. Pretreatment step	311
3.2. Feedstock cost	311
3.2.1. General comparison	311
3.2.2. Cost breakdown	312

\* Corresponding author. Tel.: +32 16 32 27 26; fax: +32 16 32 29 91.

E-mail address: [Bart.VanderBruggen@cit.kuleuven.be](mailto:Bart.VanderBruggen@cit.kuleuven.be) (B. Van der Bruggen).

3.2.3.	Future cost changes	312
3.3.	Overall ethanol yield	313
3.3.1.	Yield comparison	313
3.3.2.	Ethanol yield breakdown	313
3.4.	Enzyme cost	313
3.4.1.	General comparison	313
3.4.2.	Determination of the cellulase price	314
3.4.3.	On-site cellulase production	314
3.5.	Fixed capital investment	314
3.5.1.	General comparison	314
3.5.2.	Standard cost calculation methodology	315
3.5.3.	Capital investment cost breakdown	315
3.6.	Cash flow analysis parameters	316
3.6.1.	Standard assumed economic parameters	316
3.6.2.	Parameter differences	316
4.	Cost estimation of lignocellulosic ethanol	316
4.1.	Determination of process and economic parameters	316
4.1.1.	Current situation	316
4.1.2.	Future situation	317
4.2.	Determination of the absolute ethanol production cost	317
4.2.1.	Current MESP	317
4.2.2.	Future MESP	319
4.3.	Comparison to gasoline and first-generation ethanol	319
4.3.1.	Gasoline production cost	319
4.3.2.	Corn ethanol production cost	319
4.3.3.	Overall comparison	320
5.	Conclusions	320
	Acknowledgements	320
	References	320

## 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<sub>2</sub>) 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<sup>9</sup>) 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 worldwide, 1623 Tg (10<sup>12</sup> 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 mid-sized 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

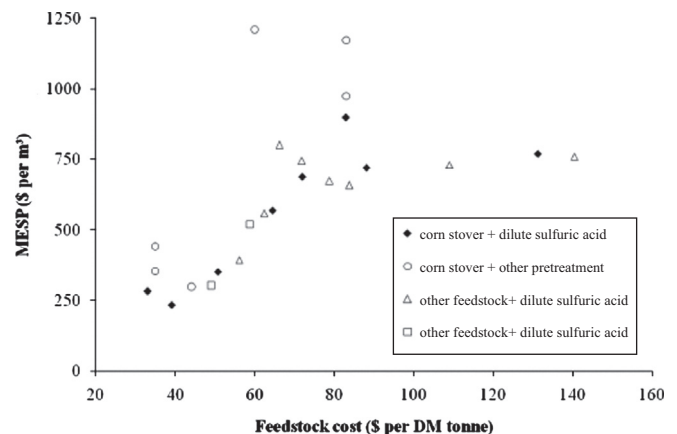


Fig. 1. General comparison of different techno-economic studies: feedstock cost vs. MESP.

Download English Version:

<https://daneshyari.com/en/article/8121410>

Download Persian Version:

<https://daneshyari.com/article/8121410>

[Daneshyari.com](https://daneshyari.com)