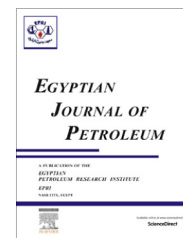




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FULL LENGTH ARTICLE

# Techno-economic and environmental aspects of the production of medium scale ligno-cellulosic ethanol under Egyptian conditions



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## KEYWORDS

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**Abstract** As a result of actual pilot experimental data and guided by international and national reported estimates, this techno-economic study on a 20,000 ton/y ethanol production plant from rice straw has been conducted. The process essentially comprises preparation of the raw materials, alkaline pretreatment, simultaneous saccharification and fermentation (SSF) and dehydration. For the proposed capacity, costs have been estimated based on published information for the equipment as updated to 2013. Operating costs have been estimated according to experimental results of the research team and published information. Financial and sensitivity analyses have been conducted for optimistic and pessimistic scenarios for investment and operating costs and varying sales price of ethanol in the range \$0.76/kg–\$0.84/kg. Results indicate that positive present values have been obtained at the prevailing discount rate of 3%. The Internal Rate of Return (IRR) exceeds the discount rate considerably for the optimistic assumptions and is rather marginal for the pessimistic scenarios. In general, the process is considered technically and economically viable.

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## 1. Introduction

With the ever increasing need for fuels in general and transport fuels in particular, increasing efforts are being directed by developed and developing countries to produce biofuels based

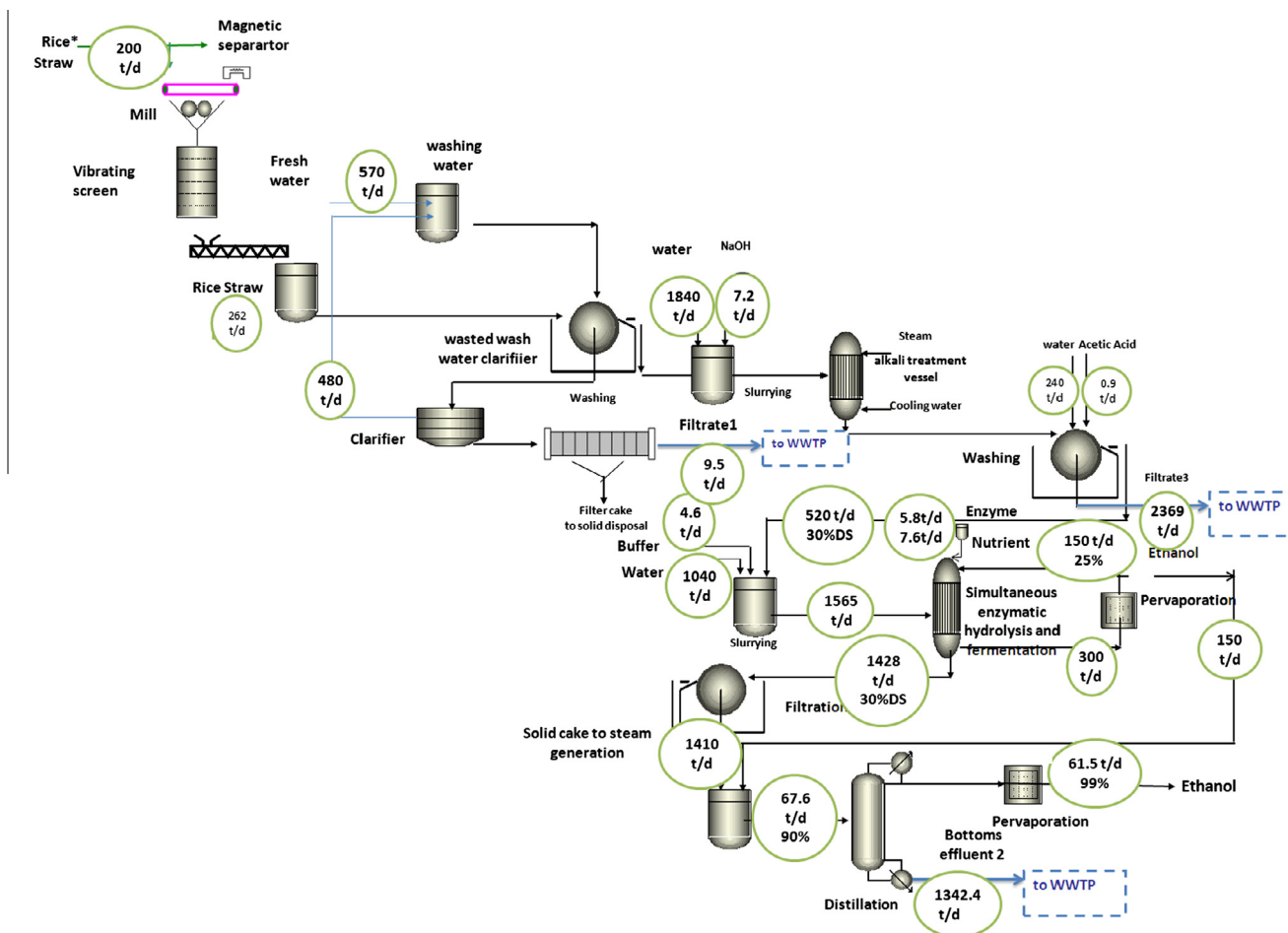
on renewable sources. On the other hand, excess agricultural residues constitute a nuisance for disposal in an environmentally sound manner. The extensive efforts undertaken by developed and developing countries for the use of several alternative ligno-cellulosic materials at bench, pilot and early demonstration stages have given positive results and commercial plants are in early operational phase or under construction. Enormous amounts of technical results have been published and have been further techno-economically analyzed to explore the prospects for commercial application. The successive processing stages as undertaken by several optional schemes in addition to the variation of costs and prices in general and

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**Figure 1** Process flow diagram and overall material balance for the proposed plant.

for site specific factors in particular resulted in a wide variation of economic indicators and appraisal as reported in the last few years. The Research Energy Laboratory of the US Department of Energy in collaboration with others published several reports addressing the issue. [1–5]. In a recent report, [1] the minimum price for sales of ethanol has been estimated to be \$2.15/gal (2007 estimates) for 2025 dry ton/day corn stover using dilute acid pretreatment process. Widely varying approaches and results have been reported. In a review [6], Gnansounou and Dauriat focused on the studies in the United States of America and in Europe, and investigated the different natures of the techno-economic evaluations during the development process of the supply chain by standard costing with respect to Value Engineering, and Target Costing based on the projected market price. The authors concluded that ligno-cellulosic ethanol is expected to be commercial in the next decade (following 2010). The capital cost and ethanol product value for a pioneer plant as compared to an  $n$ th plant constructed after  $n$  years for several optional biochemical process technologies have been evaluated. The authors concluded that the capital costs of a pioneer plant are substantially larger than an  $n$ th plant [7]. Uncertainty analysis [8] has been recently undertaken by a model which relates a process model with an economic model to identify the absolute and relative uncertainties in minimum ethanol selling price under varying process yields based on previous reported experimental data of

ligno-cellulosic ethanol from corn stover [1]. In a previous work, the techno-economic analysis of a small-scale ethanol plant from rice straw has been published [9]. In this work, a medium-scale plant of capacity 20,000 ton/y has been investigated. The substrate considered is rice straw. However, since this residue is seasonally available and other agricultural residues could be utilized throughout the year, it is assumed that various ligno-cellulosic wastes such as sugar-cane residues and cotton stalks could be utilized. In the latter case, there would be some variations in the adopted process with perhaps even improved economics. The process as based on pilot experimental results for rice straw, which is published elsewhere [10], is first briefly described. Process development is then presented. Cost estimation, financial analysis and economic indicators are discussed.

## 2. Technical and environmental aspects

### 2.1. Process description

The main plant processes comprise the following sections as presented in Fig. 1

- 1- Rice straw handling system, comprising weighting scale, forklifts for unloading and transfer of rice straw bales, rice straw storage slab and conveying belts.

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