Available at www.sciencedirect.com

INFORMATION PROCESSING IN AGRICULTURE 3 (2016) 92–98

journal homepage: www.elsevier.com/locate/inpa

Return of investment and profitability analysis of bio-fuels production using a modeling approach

Yangyang Deng, Prem B. Parajuli *

Department of Agricultural and Biological Engineering, Mississippi State University, Mississippi State, MS 39762, United States

A R T I C L E I N F O

Article history:
Received 7 October 2015
Received in revised form
17 February 2016
Accepted 28 March 2016
Available online 1 April 2016

Keywords:
Bio-gasification
Modeling
Sensitivity analysis
Profitability analysis

A B S T R A C T

The objectives of this study were to evaluate the return of investment and profitability of a bio-gasification facility using a modeling method. Based on preliminary market analysis, the results determined that the power facilities driven by biomass gasifiers could be profitable if they consider the most sensitive cost factors such as labor, project investment, and feedstock supply. The result showed that economic feasibility of bio-gasification facility can significantly affect by its production capacity and operating modes (one shift, two shifts, or three shifts). The cost analysis modeling approach developed in this study could be a good approach for economic analysis of bio-syngas and bio-fuel products. In addition, this study demonstrated a unique modeling approach to analyze return of investment and profitability of biofuels production.

1. Introduction

The production of biofuels based on renewable resources has become the most important global issue due to diminishing petroleum reserves, increasing oil price, and rising concerns about global warming [1,2]. Recently, biomass-based feedstock including wood, agricultural crops (e.g., switchgrass, and miscanthus), municipal solid waste, and aquatic plants (e.g. algae and water weed) has been considered one of the major renewable resources for the future due to a positive impact on economy and environment [3,4].

Globally, the United States and Brazil dominated the biofuel production and consumption. Based on recent reports, these two countries represented about 73% of the global biofuels production and 70% of the global biofuel consumption [5]. Biofuel production in the United States are dominated by corn-based sources, while sugar-cane are the primary crop in the Brazil. Both corn-based and sugar-cane-based biofuels were commonly produced and consumed in the past decades. In addition, France, Germany and China also contributes to the global biofuels production and consumption.

Although the use of biomass-derived fuels is well recognized an alternative energy source to fossil fuels, one of the major issues facing the biofuel sector is an economic feasibility since the existing technologies are still not in a status to commercially produce biofuel at a competitive price with current fossil fuels [5]. Compared to fossil fuels, the higher biofuel production cost may be a major barrier to its commercialization [6,7]. In addition, the various possible conversion techniques make it difficult to choose an optimal economic point for the biofuel production because the selection of conversion technique affects the production cost [4,7]. Preliminary market analysis is extensively used to find an optimal point before starting biofuels production projects.

* Corresponding author. Tel.: +1 662 325 7350; fax: +1 662 325 3853.
E-mail addresses: xiaod510148@gmail.com (Y. Deng), pparajuli@abe.msstate.edu (P.B. Parajuli).
Peer review under the responsibility of China Agricultural University.
http://dx.doi.org/10.1016/j.inpa.2016.03.002
2214-3173

Preliminary market analysis was the initial glimpse into overall environment to determine the likelihood of success for a new bio-fuels business. Market analysis survey data may include market size, location, nature, characteristics, and market capacity for economic analysis. Economic analysis can be done through market research understanding supply, and forecasting demand. According to the projects and products in the market environment, competitiveness of the market and market competitors need to be analyzed. The analysis of the products with the judgment may be needed after the project put into the market for a limited time to decide on marketing strategy [6].

Bio-chemical (e.g., methanization) and thermo-chemical (e.g., gasification, combustion, and pyrolysis) processes are extensively used for the conversion of biomass to useful energy [4,8]. Recently, biomass gasification has been considered as one of the most frequently used conversion process among them [8–10]. Bio-gasification is a thermochemical transformation of a raw biomass material into combustible gases through chemical reactions [11,12]. The produced gaseous mixture, called a synthetic gas (syngas), contains hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and other impurities such as nitrogen (N_2), alkali compounds, sulfur compounds, and tar. The cleaned syngas containing H_2 and CO can be converted into light hydrocarbon gases (Light HCs), liquid hydrocarbons (Liquid HCs), and aqueous (Oxygenates CxHyOz) through the catalytic conversion process. However, studies on market analysis for the biofuel production from biomass-derived syngas with the modeling approach are limited. Thus, objective of this study was to: (1) analyze the market price for biofuel production from a bio-gasification facility and (2) evaluate the profitability of bio-fuels production from a bio-gasification facility.

2. Materials and methods

This study utilized data and bio-gasification procedures adopted at Mississippi State University's bio-gasification facility (65 N m^3 h^{-1}). The biomass gasification facility comprised of four steps (biomass handling and preparation, gasification, syngas cleaning and conditioning, and catalytic conversion) as discussed in the previous literature [13,14]. With the given ratio comprised of essentially CO and H_2, they can be converted to a mixed bio-product with oil, gas, and aqueous. In this study, the catalytic conversion of syngas into light hydrocarbon gases (Light HCs), liquid hydrocarbon (Liquid HCs), and aqueous (Oxygenates CxHyOz) was considered.

2.1. *Preliminary market analysis*

Preliminary market analysis was conducted on the basis of total capital cost, total operating cost, total revenue, return of investment, and net revenue. The total production cost (C_{ta}) was calculated by the sum of the total capital cost (C_{ac}) and total operating cost (C_{ao}), Eq. (1).

$$C_{ta} = C_{ac} + C_{ao} \quad (1)$$

For the calculation of total operating cost, equations from previous literatures [7,14,15] were utilized in this study. They developed the cost analysis model to analyze the biofuel production from bio-gasification facility. Some of the important features included in the equations and economic assumptions were feedstock cost, electricity cost, labor cost, waste treatment cost, catalyst cost, and fixed costs (general overhead, maintenance, insurance and taxes). In addition, economic parameters such as feedstock cost of \$35 ton^{-1}, electricity price of \$0.0718 K wh^{-1}, wastewater treatment cost of \$0.731 ton^{-1}, catalyst unit price of \$145.15 lb^{-1}, and labor pay rate of \$16 h^{-1} were used in this modeling study [7,14–16], Yan Qiangu, personal communication). Annual total syngas yield, feedstock consumption, and catalysts consumption were calculated using the equations from the previous literatures [7,14,15,17] including assumption on working and operating hours (Table 1).

The mathematical equations for the biofuel products yield including CO_2, water (H_2O), gas (Light HCs), oil (Liquid HCs) and aqueous (Oxygenates CxHyOz) from syngas generation and catalytic conversion; and production cost were used from previous literature [14].

2.2. *Capital cost*

The capital cost was estimated based on the total project investment (TPI) and loan interest cost. More specifically, the TPI was calculated by adding the total installed cost (TIC) to the total indirect cost (TIDC). The TIC and TIDC were estimated based on the equipment purchase cost. This method of cost estimation has an expected accuracy of −10% to 20% [18]. The equipment purchase cost (C_{eq}) can be estimated by using the capacity factored method [7,15,17], as expressed in Eq. (2).

$$C_{eq} = C_{ex}\left(\frac{P_{c\_new}}{P_{c\_ex}}\right)^n \quad (2)$$

where C_{ex} is the equipment purchase cost of the existing bio-gasification facility, P_{c_ex} is the production capacity of the existing facility (N m^3 h^{-1}), P_{c_new} is the production capacity of the new facility (N m^3 h^{-1}), and n is a characteristic scaling exponent that is based on characteristics of the equipment related to production capacity. In this study, the n value was assumed to be 0.6 [7,15,17].

The TIC was determined using the related cost factors obtained by referring to existing literature, as presented in Table 1. The TIC was affected by many factors including purchased equipment installation, instrumentation and controls, piping, electrical systems, buildings, and yard improvements (Table 2). The TIDC was also estimated using cost factors, as

Table 1 – Three working hours of a bio-gasification facility operating in different shifts.

Mode	Unit	Working hours (H_0)	Operating hours (H)
One shift	h per year	2080	1820
Two shifts	h per year	4160	3900
Three shifts	h per year	6240	6188