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Economic evaluation of domestic biowaste to ethanol via a fluidized bed gasifier

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ABSTRACT

The economic evaluation of a biomass to ethanol process using a fluidized bed gasifier was conducted by using domestic biowastes. In this work, we chose two different scale processes because collecting biowastes was considered as one of biggest bottlenecks. Economic evaluation was conducted using internal rate of return, net present value and ethanol prices. NPVs from a 2000 dry-ton/day process and two1000 dry-ton/day process ranged from 47.9 million dollars and 69.5 million dollars in same IRR of 10%. The construction of a 2000 dry-ton/day scale plant might be more economical than two 1000 dry-ton/day scale plants because of lower ethanol prices.

Introduction

Q3 Due to excessive burning of fossil fuels since the start of industrial revolution, the atmospheric concentration of carbon dioxide has recently increased to 500 mg/L [1]. An increase in Carbon dioxide atmospheric concentration changes the global climate, causing both annual average temperature of the Earth and average sea level to rise. A large group of countries is therefore committed to the reduction of greenhouse gas emissions. The Kyoto Protocol and the Bali Road Map attempted to restrict the emissions of carbon dioxide, which accounts for the largest proportion of greenhouse gases [2]. Sustainable sources of renewable energy are being actively developed to reduce carbon dioxide emissions and replace fossil fuels [3].

Renewable energy is based on the conversion of sunlight, water, geothermal heat, and bio-organisms. Bioenergy is a sustainable energy source derived from biomass. Especially biofuels are produced from raw materials coming from agriculture, forestry, organic wastes and residues from all kind of industries [4]. Although bioenergy or biofuels emit carbon dioxide in the same way as fossil fuels, it also sequesters carbon dioxide from the atmosphere during growth and has therefore been acknowledged as carbon neutral [5].

Bioenergy produced from biomass is used as a fuel for combustion or for gasification and can be used in electricity production, heat generation, and chemical production [6]. Also, biomass resources can be converted into biofuels such as bioethanol or biodiesel [7]. Especially bioethanol is a very effective energy source that can partially replace gasoline. Generally, the ethanol content of motor gasoline does not exceed 10% by volume, but gasoline with 10% ethanol content has been known as E10 and gasoline with 15% ethanol content has been known as E15 [8]. Its main commercial production has been done in the United States and Brazil [4] and E10 or E15 are commercially distributed and sold by using current gasoline infrastructures in U.S. and Brazil [9]. They are recognized as an eco-friendly, renewable, and economically viable energy source. In contrast with the U.S. and Brazil, where biomass has been widely used for bioethanol production, production elsewhere has not yet become widespread because of the high cost of large-scale production capacity. However, bioethanol could be one of promising options to meet Korea's 2015 Renewable Fuel Standard (over 3%) [10].

Sugarcane and corn which have been generally used for bioethanol productions are not only popular sources of biomass for bioethanol production but also food sources for both humans and animals. An increase in bioethanol production therefore leads to an increase in planting of the two crops. However, there is a limit on the production of sugarcane and corn due to limitations on arable land and nutrient provision and concerns over environmental impacts such as land degradation. Competition with food resources also increases the price of sugarcane and corn. Therefore,

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raw materials for biofuels are being steered toward non-edible resources such as woodchip and rice husks [2].

Non-food biomass resources include forestry products, agricultural byproducts such as lignocellulose, and organic waste. Research on energy conversion of non-food biomass resources has led to the adaptation of thermochemical conversion processes [11] such as pyrolysis, combustion, and gasification. Especially gasification processes for syngas which is mostly composed of hydrogen and carbon monoxide have been developed through mixing with coal [11], petroleum cokes [12], combustible wastes and biomass [13]. Also, the usage of syngas has been proposed as a resource in automotive fuel fuels production [14], in electricity generation using gas engine [15] and alcohol synthesis [16].

The shift from edible biomass to non-edible biomass is challenging because of the massive scale of development that is required to achieve economically feasible thermo-chemical conversion processes. The massive fuel supply necessary for commercial-scale production will incur significant collection costs. This has remained a big hurdle for biomass energy conversion. Also, there are many types of biomass resources, widely distributed and with different harvesting periods. This makes it difficult to predict the amount of biomass that will be available for energy production. However, a recently developed map of Korean non-edible biomass resources makes it possible to quantify the usable biomass resources available in Korea [3]. Because of broad distribution of biomass resources [2], it is essential to evaluate the cost of collecting biomass for commercialization of biomass energy conversion processes. Generally an increase of plant scale might result in a decrease of production cost [16], but the bigger plant needs more raw materials. Because of broad distribution of biomass resources, an increase of plant scale would result in a shortage of raw materials and affect commercial value. Therefore, the comparison of the changes in plant scale and collection costs should be analyzed which one is more sensitive to economic feasibility.

In this study, we conducted a techno-economic feasibility analysis of thermo-chemical biowastes to ethanol conversion processes with different scales based on the domestic biomass resource map. Because there is no data about collection amount of biomass in resources map, the economic evaluation of bio-ethanol production process carried out by using data from the report of Ministry of Environment [17]. Also, the effect of various costs on economical values of proposed processes were evaluated in this study. The economic feasibility analysis of alcohol conversion of biomass waste can form the basis for national energy resource planning, industrial development, and policy decision-making.

Methods

Description of a biowaste to ethanol process via gasification and alcohol synthesis

The proposed domestic biowastes to ethanol process flow via gasification and alcohol synthesis was described in Fig. 1. Even though thermo-chemical biowastes to ethanol processes have been proposed and developed, a commercially operated process have not been realized until now. The proposed process of ethanol production including both gasification and alcohol synthesis shown in Fig. 1 had been introduced by the National Renewable Energy Research Institute (NREL) in the United of America [18]. As shown in Fig. 1, the complex process reviewed in this study can be divided into a dry stage, gasification, gas clean-up, conditioning, alcohol synthesis, separation, and heat and power generation.

The dry stage accommodates the removal of moisture in biomass, the delivery of biomass feedstock, short term storage on-site, and the preparation of the feedstock for processing in the gasifier. The gasification block converts dry biowastes and gasification agents into syngas and char. The gasification reactor concept used in this evaluation was shown in Fig. 2 [19]. As shown in Fig. 2, a dual circulating fluidized bed gasifier have been developed and adopted for converting non-edible biomass into syngas [14]. The dual circulating fluidized bed gasifier composed of combustor, gasifier, cyclone separators and scrubber. The gasifier region and combustor region are separated from each other for preventing the mixing of combustion gas with the syngas, but fluidized materials circulated between the two interconnected reactors might transport required heat for endothermic gasification reaction [14]. The gasifer operating conditions, results and cold gas efficiencies are written in Table 1. In Table 1, mass flow and gas composition were calculated at the basis of 2000 ton/day scale. Since there is no commercially operating gasifier for domestic biowastes, cold gas efficiencies was fixed in this study. H_2:CO molar ratio of syngas was calculated to 0.6. Syngas produced by the gasification process is refined and reformed before being compressed for injection into an ethanol synthesis reactor [18].

Gas clean-up and conditioning stage should be used to increase the yield of ethanol. The undesired hydrocarbon materials such as CH_4, C_2H_6, C_2H_4, tars in syngas are reformed to additional CO and H_2, while particulates are removed by quenching. Acidic gases (CO_2 and H_2S) are removed, and then the purified syngas is compressed. Tar reforming stage composed of bubbling fluidized tar reformer, quench chamber, acid gas scrubber, and compressor. The operation conditions and results

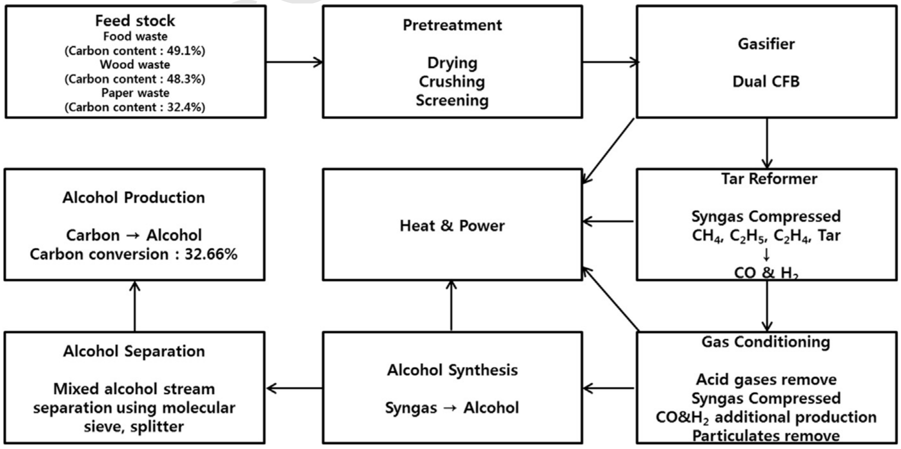

Fig. 1. Ethanol production process flowchart.

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