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Review

# Economics of biodiesel production: Review

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ABSTRACT

Biodiesel is an alternative fuel similar to conventional diesel. It is usually produced from straight vegetable oil, animal fat, tallow, non-edible plant oil and waste cooking oil. Its biodegradability, non-toxicity and being free of sulfur and aromatics makes it advantageous over the conventional petrol diesel. It emits less air pollutants and greenhouse gases other than nitrogen oxides. In addition, it is safer to handle and has lubricity benefits than fossil diesel. However, with all these environmental benefits, biodiesel could not be extensively applied as a complete substitute fuel for conventional diesel. The main reason, repeatedly mentioned by many researchers, is its higher cost of production. Reduction of the cost of biodiesel production (unit cost of production) can be attained through improving productivity of the technologies to increase yield, reducing capital investment cost and reducing the cost of raw materials. These demand a thorough execution of economic analysis among the available possible technology alternatives, catalyst alternatives, as well as feedstock alternatives so that the best option, in economic terms, can be selected. With this respect, there are a number of researches done to investigate economically better way of producing biodiesel as a substitute fuel. Accordingly, this paper is meant to review the researches done on economics of biodiesel production, emphasizing on the methods of assessment and determination of total investment cost and operation cost, as well as on assessment of economically better technology, catalyst and feedstock alternatives. It also gives emphasis on profitability of biodiesel production and the major system variables affecting economic viability of biodiesel production.

## 1. Introduction

The world total energy consumption has been significantly increasing [1]. According to the International Energy Outlook 2016 (IEO2016) projection, the total world consumption of marketed energy expands by 48% from 2012 to 2040. The larger share of such growth in world energy use goes to countries outside of the Organization for Economic Cooperation and Development (OECD) [1]. In these countries, economic growth and population expansion are driving forces for energy consumption. In an economy experiencing considerable economic growth, living standards improve resulting in demand for more energy per capita. This together with population growth inevitably boost up the total energy consumption.

Currently the most dominant resources for world energy supply are crude oil, coal and gas [2]. However, the limited reserve of such fossil fuels prompts the consideration of alternative fuels from renewables. Most renewables do have environmental advantages over the conventional fuels, such as net greenhouse gas and pollution reduction [3]. These environmental advantages are additional points to strengthen the concept of replacing the fossil fuels with renewable energy sources. In line with this, the IEA Renewable Energy Medium Term Market Report 2016 indicated that the renewable energy share in the total world energy consumption is expected to have at least 39% increment by 2021 [4].

According to the Organization of the Petroleum Exporting Countries, OPEC [5], by 2040 world fuel oil demand will reach up to 109.4 million barrel per day from which, diesel fuel demand is expected to dominate by 5.7 million barrel per day as shown in Fig. 1.

However, this higher oil fuel demand is facing two major challenges, scarcity of the resource and negative environmental impact due to its use. These two challenges alone can impose an urge towards looking for better and long lasting substitute fuel. Accordingly, many researchers are becoming interested in investigating alternative energy resources. Among such alternatives, biodiesel is getting more emphasis for some reasons. It can be produced from a wide variety of resources including wastes like waste cooking oil, oily sludge from factories and waste animal fat [6,7]. In addition, there are a number of technological choices to produce biodiesel based on the quality of the feedstock, giving possible alternatives to minimize overall production expenses [8].

When it is compared to conventional petrol diesel fuel, biodiesel has no sulfur. It also produces less carbon monoxide, particulate matters,

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*Acronyms*

| | |
|---|---|
| AEC | Annualized Total Investment Cost |
| AOC | Annual Operational Cost |
| ARR | After-tax Rate of Return |
| ASTM | American Society for Testing and Materials |
| BBP | Biodiesel Break-even Price |
| BPC | Biodiesel Production Cost |
| CIC | Capital Investment Cost |
| CD | Catalytic Distillation |
| DCFR | Discounted Cash Flow Rate of return |
| FAME | Fatty Acid Methyl Ester |
| FCC | Fixed Capital Cost |
| FCI | Fixed Capital Investment |
| FOB | Fixed on Board |
| HCl | Hydrogen Chloride |
| IEA | International Energy Agency |
| IRR | Internal Rate of Return |
| ISBL | Inside Battery Limits |
| NNP | Net Annual Profit after Taxes |
| NPV | Net Present Value |
| NPW | Net Present Worth |
| OECD | Organization for Economic Cooperation and Development |
| OPEC | Organization of the Petroleum Exporting Countries |
| OSBL | Outside Battery Limits |
| PBP | Pay Back Period |
| PFR | Plug Flow Reactor |
| R&D | Research and Development |
| ROI | Return on Investment |
| SIC | Specific Investment Cost |
| TCC | Total Capital investment Cost |
| TEC | Total Equipment Cost |
| TMC | Total Manufacturing Cost |
| UPC | Unit Production Cost |

smoke and hydrocarbons and has more free oxygen than the conventional petrol diesel [3,9]. Having such more free oxygen results in complete combustion and reduced emission [10,11]. Biodegradability, higher flashpoint and inherent lubricity are other worth mentioning advantages of biodiesel over the conventional petro diesel [12].

The major challenges associated with biodiesel as a fuel are, having higher cost of production, having relatively less energy content compared to fossil diesel and releasing nitrogen oxide emissions when it is burnt [13]. However, it is usually the higher cost of production that makes the fuel not to be extensively used [14–16]. Succinctly, there are three possible paths to attain unit cost reduction concerning biodiesel production processes such as improving the production technologies for better productivity/yield, reducing capital cost and reducing raw material cost for which feedstock cost is the most dominant [17,18].

All of these possible paths demand economic analysis to be done among various alternative production technologies, catalysts, feedstock types as well as various biodiesel and glycerol purification technologies to pinpoint economically better ones. There are a number of worth mentioning investigations performed to test economics of biodiesel production processes.

Accordingly, in this paper more emphasis is given on reviewing the various studies done to investigate the economics of biodiesel production related to determination and comparison of total cost of investment, direct production costs as well as various system variables affecting profitability among different production technology types and production scales.

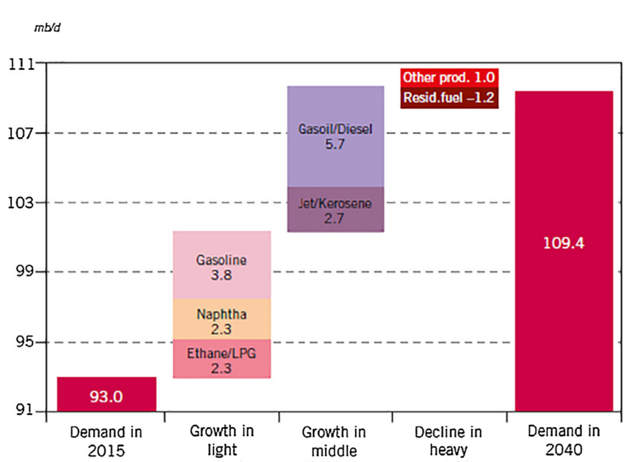


**Fig. 1.** Oil demand growth by type from 2015 to 2040 [5]

## 2. Methods to assess total investment cost for biodiesel production

The total investment cost to produce biodiesel vary depending on a number of factors like the type of production technology chosen, the production scale (plant size), type and market price of raw materials used, among others. The total investment cost can be categorized into fixed capital investment cost and operating (working capital investment) cost [19]. Fixed capital investment cost represents the capital necessary for the installed process equipment with all auxiliaries, which are desirable for comprehensive process operation whereas operating cost considers raw materials cost, utility cost, labor dependent costs, facility dependent costs and other similar variable expenses required for manufacturing of the biodiesel at a given rate.

A number of studies have been done on estimation of the total investment cost of biodiesel production, one different from the other in terms of cost considerations and the approach to calculate the required cost categories for a given production scale.

### *2.1. Capital investment cost*

There are five known classifications of capital investment cost estimation ways in chemical processing industries[20]. These are order-of-magnitude estimates (class 5), study estimates (class 4), preliminary estimates (class 3), definitive estimates (class 2) and detailed estimates (class 1)

The capital cost estimates done using order-of-magnitude and study estimates are usually for preliminary feasibility analysis to compare process alternatives. The other two classes (preliminary estimates and definitive estimates) are employed to further carry out accurate estimation of the capital cost on the profitable process alternative screened using class 5 and/or class 4. Eventually, detailed estimates is usually applied as the final detail estimation of all the costs associated with the construction of the new plant so that a construction decision could be done based on the estimate[20].

Various researches that are done to estimate the capital investment cost for biodiesel production, make use of the study estimate approach, which is usually performed to give an overview on the economic feasibility of potential technological alternatives [18,21,22].

The major cost categories under capital investment cost are equipment purchasing cost and direct plant costs. Direct plant costs include those required for equipment installation, instrumentation, piping, electrical facilities, yard improvement, auxiliary facilities, among others. There are different techniques to calculate the fixed capital investment cost for biodiesel production processes. In all of these techniques, the primary activity demands estimation of total equipment cost