Journal of Agriculture and Forest Meteorology Research

JAFMR, 2(1): 51-57
www.scitcentral.com

Original Research Article: Open Access

Economic Analysis of Biodiesel from Chlorophyceae and Palm Oil in Riau Province, Indonesia

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Received March 26, 2018; Accepted August 21, 2018; Published January 11, 2019

ABSTRACT

Chlorophyceae and Oil Palm in Riau province is a potential commodity to be the producer of biodiesel in the future. But the cost of biodiesel production becomes one of the barriers to fuel conversion program to biodiesel countries including Indonesia in an effort to anticipate the occurrence of the energy crisis. One of the causes of high production costs is because the variable cost of production comparable so far has not fully reflected the overall potential contained in biodiesel. Potential biodiesel belonging to environmental commodities such as renewable properties, low in land use, and environmentally friendly needs to be included in the calculation in order to obtain an objective calculation comparison. This study aims to evaluate the effect of the addition of environmental commodities on the cost structure of biodiesel production from oil palm oil and Chlorophyceae oil. The value of environmental commodities is estimated by the method of benefit transfer method and to show the value of profit used the approach of willing to pay (WTP). The values of environmental commodities are based on the results of the calculation of Environmental Priority Strategy (EPS) software version 2000. For the case in Riau province, Indonesia, EPS environmental commodity value is inferred by elasticity based on the comparative value of per capita income of Sweden and Indonesia. The result of the study found that life cycle costing (LCC) analysis applied by adding externality variable can give detailed information about biodiesel production cost composition and can be used as a method to get the most competitive total production cost from several sources. So the externality variable of course also influences the total increase of biodiesel production cost up to 14%. From the profitability analysis shows that the supply of biomass of Chlorophyceae for biodiesel production is more secure and sustainable than the oil palm biomass due to technical and non-technical constraints, while the production of Chlorophyceae biomass is more easily overcome. In addition, the advantages of its role in GHG mitigation which also enlarge the opportunity as the main material of biodiesel in the future of course.

Keywords: Economic, Externality, Biodiesel, Oil palm, Chlorophyceae oil, Fuel, Renewable fuel

INTRODUCTION

The province of Riau is one of the vast areas of oil palm plantations in Indonesia. In addition, the general, brackish and marine waters of Riau contain Chlorophyceae resources, especially Chlorophyceae, which are very large in number. Meanwhile, biodiesel resources sourced from fossils in the future are predicted to experience a national energy crisis. World Bank data of 2002 states that within 20 years between 1980-2000, almost 90% of the energy used for development in Indonesia derived from the three main sources of fossil energy such as coal, petroleum, and natural gas, while non-fossil energy (Bayu, geothermal and solar energy) and energy from biofuels are not significantly developed [1]. One effort to reduce dependence on fossil energy is to look for alternative renewable energy sources such as biodiesel from palm oil, corn, distances and other food crops [2].

In order to reduce the high dependency on the fuel, the Indonesian government is conducting fuel conversion program to gas fuel (LPG-liquor petrol gas) [3]. In the same effort, the government has also promoted the effort of non-fuel energy diversification by stipulating Presidential

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Citation: Eddiwan K. (2019) Economic Analysis of Biodiesel from Chlorophyceae and Palm Oil in Riau Province, Indonesia. J Agric Forest Meteorol Res, 2(1): 51-57.

Regulation no. 5/2006. Peppers are targeting the use of renewable energy in which contained alternative energy sources of biofuels such as bioethanol, biodiesel as much as 5% by 2025. Biodiesel BBN is usually produced from coconut oil palm oil (crude palm oil), while bioethanol derived from molasses, corn, cassava and tubers [4]. The Indonesian Association of Biofuel Producers (APROBI) states that Indonesia's total annual production of biodiesel and bioethanol is increasing rapidly from 0.65 million litres and 0.194 million litres in 2011 to 0.7 million litres and 0.2 million litres. However, the increase in biofuel production is still far from the Perpres scheme that targets the annual use of biofuel and bioethanol in the 2011-2015 periods of 4.52 million litres and 2.78 million litres [5].

Various efforts to popularize and market biodiesel (biodiesel), i.e., mixing CPO with diesel fuel into vehicles, but the number are still very limited [6]. If a mixture of CPO in diesel is propagated, it is feared to affect CPO stocks for cooking oil/other foodstuffs [7]. Other obstacles that remain unresolved are the production cost structures that depend on the scale of production, the unconsolidated market structure, the limitations in infrastructure either for processing, or for distributing and transporting biomass, the limitations of cultivation methods, the availability of water, seeds and fertilizers, the conservation of biodiversity as well as the limited networking in logistics and distribution [8].

In addition to these technical constraints, the conversion efforts of biofuels turned out to be a debate among researchers and environmentalists because the contribution of biodiesel production is actually adding greenhouse gas emissions resulting from land use change [2,9], threatening supply of food, and increase forest destruction and biodiversity. The biomass of Chlorophyceae gets top priority in becoming a candidate as one of the biodiesel materials. Advantages of Chlorophyceae biomass is a renewable energy source [10] that has the capability to reduce CO_2 emissions. Chlorophyceae utilizes sunlight to convert CO_2 into carbohydrates, fats and proteins with much more efficient productivity compared to land plants. Chlorophyceae has double time growth of about 3.5 h, requires less water in its growth and is able to produce biofuel feedstock 15-300 times faster than land plants [11].

The high productivity of Chlorophyceae to be an economical and environmentally friendly source of biofuels has attracted the attention of businesspeople and researchers. Laboratory-scale studies and pilot-project scales on the utilization of Chlorophyceae as a biofuel feedstock have been widely used [12]. Process handling ranging from purification and selection of strains, biomass production operations, harvesting has been well controlled, but its application to become a lucrative business activity still requires longer stages [13]. Refinery biofuel from Chlorophyceae biomass is still debatable in its economic and ecological merit.

In this article, the author seeks to evaluate the cost composition of biodiesel production from Coconut Palm and Chlorophyceae biomass, the ratio between the total cost of natural production and the total cost of production after the calculated component of environmental commodities. It also discussed the steps to optimize biodiesel as a competitive alternative energy source in Riau province, Indonesia.

MATERIALS AND METHODS

Life cycle costing (LCC)

Economic analysis used herein in the form of life cycle costing is one method of economic analysis to determine all production costs incurred by a process of production of goods ranging from the process of selection/supply of raw materials, installation Production equipment, operational activities, equipment maintenance to the final utilization of the product. In this research, all the cost of the production process of oil palm biodiesel and Chlorophyceae oil is divided into 3 stages, namely the production of fresh fruit bunches (TBS) or Chlorophyceae biomass, production of crude palm oil (CPO)/Chlorophyceae oil and biodiesel production. All data at each stage based on the raw materials used, the energy used and the energy produced meet the level of economic validity of the data, the data of oil palm biodiesel production is taken from 4 oil palm plantations of 10,000 ha with productive period of 15-25 years, while the production data of Chlorophyceae oil biodiesel is taken from 4 production activities of Chlorophyceae biodiesel with production capacity about 40 ton/ha/year. Comparison of cost components between biodiesel from Palm oil and Chlorophyceae oil of official price of biodiesel applicable in the Indonesian market.

Calculation of externalities

The use of biodiesel from biomass materials such as Palm Oil and Chlorophyceae oil is believed to support the mitigation efforts of greenhouse gas emissions because biodiesel burning produces fewer CO_2 emissions than fossil fuels. However, burning from this biodiesel also causes other environmental impacts such as reducing biodiversity and increasing greenhouse gas emissions due to land use for oil palm or Chlorophyceae. In addition, a clean greenhouse gas balance can also be negative because biodiesel production processes may require more energy than fossil fuels. Therefore, in order to determine the total environmental costs due to environmental loads resulting from the production of biodiesel such as land use, social costs, fossil fuel consumption, air pollutant emissions, i.e., CO_2, CH_4 N_2O, CO, NOx, SO_2, VOC and PM10, on oil palm biodiesel and Chlorophyceae oil will be taken into account.

The techniques of land assessment used as a cultivation area of Palm Oil and Chlorophyceae cultivation containers are calculated based on market price approach. The formulations used to take into account the economic value of the land are [3]:

$$V_p = \sum(P_{pi}.H_{pi})$$

Information:

V_p=Economic value of land (Rp/ha/year)

P_{pi}=Productivity of agricultural land of type I (ton/ha/year)

H_{pi}=Price of food product type (Rp/ton)

Social costs are costs incurred due to social problems such as conflicts due to land use for plantations, relocation of the population or problems of social conflict resulting from the operation of biodiesel production. Determination of social costs is done by estimating the value of 2-3% of all investment costs. Fossil fuel consumption is the amount of fossil fuel (gasoline/ diesel/coal) used in the whole stage of biodiesel production with metric joules (MJ). To facilitate the calculation of energy consumption, each litre of biodiesel produced is assumed to have as much energy as 44.2 MJ.

Air pollutant emissions are assessed and approximated by the benefits transfer method. Methods are used to assess intangible commodity by collecting information relating to the assessment of environmental commodities in one place and at the same time. The results of the environmental commodity assessment can then be used to inference data on the economic values of environmental commodities in other places or time.

Furthermore, to demonstrate the advantages of the benefit transfer method, the commonly used approach is the willingness to pay (WTP) approach. In this study, the researchers used the environmental commodity economic values from the results of the calculation of Environmental Priority Strategy (EPS) software version 2000. The value of EPS environmental commodities is inferred by the elasticity of paying ability of the applicable country/location [14]. Thus, the adjustment of environmental commodity values from EPS to the value of Indonesian environmental commodities based on the comparative value of per capita income of the country of Sweden and Indonesia. **Table 1** presents the costs of environmental commodities from burning biodiesel to Indonesia as calculated from the value of PAP (for European countries). WTP for Indonesia (WTPIna) is calculated by comparing with the European value (WTPEU) using the value of per capita domestic income (GDP).

Table 1. The value of environmental commodities from the burning of each litre of biodiesel in Riau, Indonesia.

Categories of environmental commodities	Units	Biodiesel (Rp per unit)*
Land use	Ha per year	61.704
Social conflict	Rp. Per year	125
Air pollution		
CO_2	Kg CO_2	434
CH_4	Kg CH_4	10.744
N2O	Kg N_2O	151.298
CO	Kg CO	1.302
NOx	Kg NOx	8.414
SO_2	Kg SO_2	12.918
VOC	Kg VOC	8.455
PM10	Kg PM10	142.450

**Based on the rupiah exchange rate 9.200 IDR per EUR (http://www.xrate.com)*

Biodiesel production

Production of biodiesel from palm oil: Biodiesel production process from Palm Oil consists of several stages, namely the cultivation stage of Palm Oil, CPO production stage and biodiesel production stage. The whole of the biodiesel production system from the oil palm oil is described in detail and represented in **Figure 1a**. At the stage of coconut oil palm, cultivation consists of planting and enlargement of oil palm plantation in the oil palm plantation. Materials and energy required at this stage include plantation land, fertilizer, herbicide/pesticide medicines, water and seeds of oil palm. While the resulting output is fresh fruit bunches (fresh fruit bunches, FFB) and emissions derived from the use of fertilizers, drugs and agricultural machinery used. At the stage of oil palm production process consists of several processes, among others: harvesting FFB, cooking and sterilization FFB, separation of empty fruit bunches (EFB), crude oil extraction, decanter cake separation, fibre separation, kernel extraction and palm kernel extract (PKE). Biodiesel cultivation stage begins with transesterification of Palm Oil with the help of sodium hydroxide (NaOH) and methanol catalysts. The required process inputs are CPO, water, electric energy and catalyst, while the output produced is methyl ester palmitate (biodiesel), glycerol and wastewater.

Production of biodiesel from Chlorophyceae oil: The production process of biodiesel from Chlorophyceae oil also consists of 3 stages namely Chlorophyceae culture stage in culture pond or photobioreactor, Chlorophyceae oil production stage and biodiesel production stage. The whole of the biodiesel production system of Chlorophyceae oil is represented in **Figure 1b**. At the cultivation stage, an important activity process is a process of cultivating Chlorophyceae in a pond or photobioreactor and harvesting process. In cultivation activities, expertise is needed in terms of controlling the administration of nutrients for Chlorophyceae and maintaining the condition of the media to always be in the ideal concentration for the growth of Chlorophyceae. While at the harvesting stage is still reviewed the optimal operational alternatives because at this stage absorb a lot of energy. The process of producing Chlorophyceae and biodiesel lipid production is similar to the stage of CPO and biodiesel production process in Palm Oil. The important thing that distinguishes it is the sonication process that is the process of breaking the walls of Chlorophyceae which absorb much energy and catalyst solution.

RESULTS AND DISCUSSION

Determination of Life Cycle Costing (LCC)

The costs incurred in the production of oil palm biodiesel and Chlorophyceae oil based on the production system as shown in **Figure 1a** are detailed in **Table 2**. From the comparison of the cost composition of biodiesel production from coconut palm biomass and Chlorophyceae **(Table 2)** important, among other things, the largest cost component of production lies in the cost of production of biomass (CPO/oil Chlorophyceae) which reaches 51.23% in oil palm coconut and 62.3% in Chlorophyceae. This information gives attention to biofuel observers, that in order to introduce biodiesel prices to be more economical it must be pressed on the cost of producing biomass of Chlorophyceae or fresh fruit bunches (TBS) of Palm Coconut. The cost savings of biomass production by way of efficient the process of land preparation and the operation of oil palm cultivation and the process of harvesting and saving electrical energy in the process of cultivating Chlorophyceae.

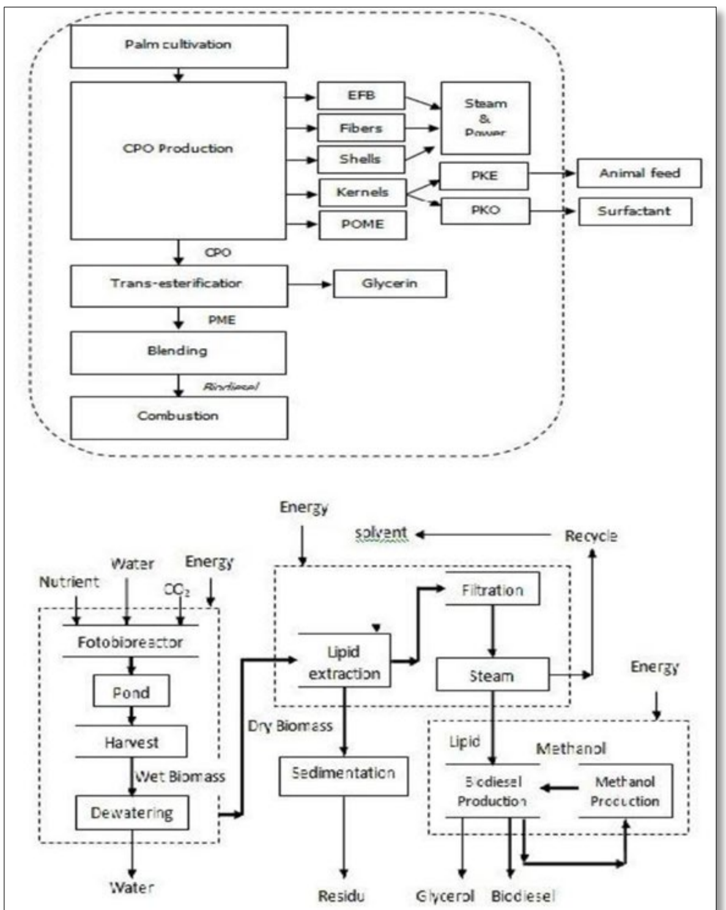

Figure 1. Scheme of biodiesel production from (a) Palm Oil and (b) Chlorophyceae.

Table 2. Composition of production costs and externality costs on biodiesel production from biomass Chlorophyceae and coconut oil palm.

Process/Materials	Chlorophyceae		Palm oil	
	Rp	Total Rp	Rp	Total Rp
Cultivation		5.955 (62.30%)		4.680 (51.23%)
a. Land preparation	1.367		3.032	
b. Fertilizer	778		330	
c. Other materials	27		353	
d. Harvest	3.783		974	
Chlorophyceae oil production		1.683 (17.61%)		1.445 (15.82%)
a. Methanol	851		667	
b. Other materials	163		330	
c. Electrical energy	453		236	
d. Heat energy	217		212	
Other Biodiesel Production		1.095 (11.46%)		997 (10.92%)
a. Methanol	480		393	
b. Other materials	63		188	
c. Electrical energy	416		283	
d. Heat energy	136		133	
e. Taxes and others	190		393	
f. Labor	127		338	
Externalities		317 (3.31%)		730 (7.99%)
a. Land value	309		961	
b. Environmental	197		196	
c. Social costs	2		125	

Influence of external cost

The cost of externalities of biodiesel production from Chlorophyceae is smaller which is about 5% compared to palm oil palm which is about 14%. This information can be a consideration for the energy policy makers in Indonesia. If CPO is selected to be biodiesel material, then the consequence is every litre that produced environmental burden in the form of contamination equal to 14%. In the production of biodiesel from Chlorophyceae widely used chemicals, namely methanol for the esterification-transesterification process, chemicals for sterilization and some inorganic fertilizers. The use of these chemicals needs to be aware of because they are potentially polluting the environment, so efforts are needed to neutralize these materials before being discharged into the environment or reused in the production cycle.

Figure 2 shows the ratio of total production cost and externality cost per litre of diesel production, Chlorophyceae biodiesel and Palm Oil biodiesel. When the cost of fuel production is calculated without taking into account the cost of externality, the production of diesel, biodiesel Chlorophyceae and Palm Oil biodiesel is around Rp. 6.992; Rp. 9.050 and Rp. 7.852. Of the 3 production prices, the price of Chlorophyceae biodiesel is not competitive because its production cost is above the diesel market price of Rp. 8.500. Following only the market price and under diesel, fuel supply conditions are always available; both biodiesel opportunities from both Palm Oil and Chlorophyceae to become fossil fuel substitutes become small.

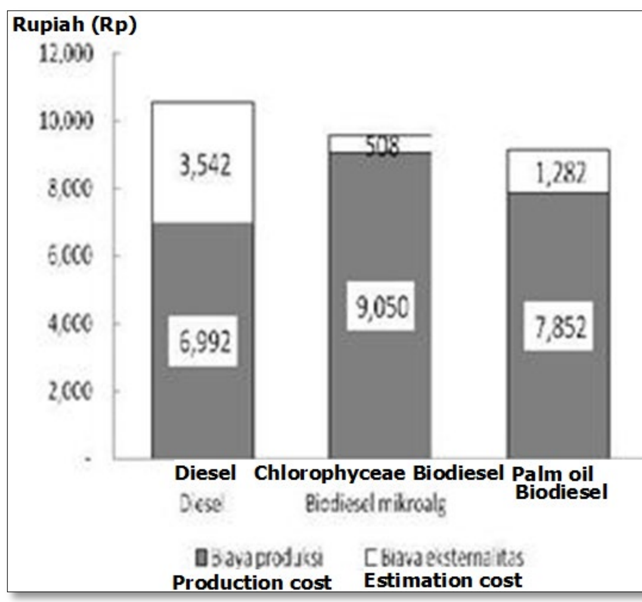

Figure 2. Comparison of production cost and cost of diesel externalities, palm oil biodiesel and Chlorophyceae biodiesel.

In the future, external costs consisting of land use costs, environmental and social costs are a must for inclusion in the cost structure of goods/services production. This additional cost of externalities will affect the total production cost of goods/services. In the production of diesel, taking into account the cost of externalities, the cost of production of 1 L diesel to Rp. 10.534 or up about 33.6%, while for the production cost of biodiesel of Palm and Chlorophyceae each rose to Rp. 9.134 (14%) and Rp. 9.558 (5%). From the analysis of data between Chlorophyceae biodiesel and Palm Oil biodiesel, stated that every production of Chlorophyceae biodiesel causes an environmental load of 5% while from Palm Oil biodiesel to burden the environment by 14%. What is meant by the environmental burden here is to eliminate the cost of environmental improvement that should be paid by the producer/consumer because the cost is not taken into account in the market? The burden of the environment will be higher along with the increased production and consumption of biodiesel. If Indonesia's biodiesel consumption from oil palm averages 600,000 kL/year [15], the environmental burden is estimated to be around 2.1 trillion per year. Comparison of the external cost percentage of Chlorophyceae biomass which is about 5% smaller than Palm Oil will be the main consideration for determining the priority of selection of biomass sources.

DISCUSSION

Based on the LCC analysis results stated that the high cost of biodiesel production is due to the high cost of CPO production/Chlorophyceae oil. The price of CPO and Chlorophyceae oil dominates production costs by about 51.2% and 62.3%, while other high costs are methanol solvents about 12%. Methanol solvents are usually used in the extraction process to extract the oil than to separate the methanol oil mixture by adding a mixture of water and hexane. The high cost of solvent usage is a challenge for researchers to look for more efficient and economical technology alternatives. Internalization of the cost of externalities on biodiesel production changes the total cost of biodiesel production from Chlorophyceae and Palm Oil. The addition of external costs to the cost of biodiesel production resulted in an increase in the production cost of CPO biodiesel and Chlorophyceae biodiesel respectively by 14% and 5%.

The total cost of biodiesel production by adding external cost causes biodiesel prices not competitive when compared to fuel prices, so to encourage the conversion program of fuel to biodiesel is not only required subsidies but also must be applied strategy by raising the importance of externalities. As an illustration, if Indonesia's biodiesel consumption from oil palm averages 600,000 kL/year annually, the environmental burden to be borne by society is estimated at around 2.1 trillion per year.

Judging from the sustainability of the biomass supply for biodiesel production, the Chlorophyceae biomass is more potential than the Palm Oil biomass. Oil Palm Biomass is constrained by increasing CPO productivity (land, social conflicts, FFB conversion to CPO) is also constrained by competitors of CPO users for foodstuffs. On the other hand, the production of Chlorophyceae biomass has great potential for further development. Chlorophyceae biomass production is unencumbered by land use and social conflicts. The conversion value of Chlorophyceae biomass to Chlorophyceae oil is still very likely to be enhanced by the treatment of certain nutrient restriction and light penetration modification to the culture medium. Another advantage of Chlorophyceae biomass is its great role in GHG mitigation, where Chlorophyceae culture media absorbs more GHG emissions than Coconut palms [16,17].

In order to encourage the fuel conversion program to biodiesel, some efforts that need to be done by the Indonesian government, among others, by increasing the price of biomass more competitive by reducing the cost of biomass production and utilizing the resulting sampling product. In the production of 1 ton of Chlorophyceae biodiesel usually produces waste of 3.12 tons of fibre and glycerol by-products of about 240 kg. When the price of Chlorophyceae biomass fibre is Rp. 500/kg and the price of glycerol at 1.28 US $/kg, the utilization of waste and byproducts will save the production cost of Rp. 2.856/kg of biodiesel. Utilization can also be done with the utilization of wastes such as waste water culture media and chemical waste by processing the funds again in the production system will enable the cost of producing biodiesel Chlorophyceae.

CONCLUSION

The LCC analysis applied by adding an externality variable can provide detailed information on the cost composition of Chlorophyceae biodiesel production and an ideal cost-of-cost comparison (eco-friendly) when compared to the total cost of biodiesel production of Palm Oil and fossil diesel. The cost of biodiesel production is mostly absorbed for the production of Chlorophyceae oil and CPO which accounted for 62.3% and 51.2% of the total cost of biodiesel production. This information provides lessons for biodiesel business managers if they want to make efficient production costs should concentrate on CPO/oil Chlorophyceae production stage. Externality variables also influence the total cost of biodiesel production up to 15% with the three biggest cost components including land use cost, fuel usage and social conflict. The biomass supply of Chlorophyceae for biodiesel production is more secure and sustainable than the Palm Oil biomass due to technical and non-technical constraints on the production of Chlorophyceae biomass easier to overcome as well as the advantages of its role in GHG mitigation which also widened the opportunity as the main biodiesel material in the future.

ACKNOWLEDGEMENT

The award was presented to the University of Riau, which has supported this research. Further thanks to the Dean of the Faculty of Fisheries and Marine and all Water Laboratory Biology Assistants who have assisted this research activity.

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