Estimation of biodiesel production from used cooking oil of university cafetaria to support sustainable electricity in Universitas Pertamina

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Abstract. The objective of this study was to estimate the amount of biodiesel production obtained from the used cooking oil from the university canteen. This research is a literature review supported by the existing condition data of canteen activity at Universitas Pertamina, especially from the amount of used cooking oil produced. Based on the survey questionnaire, the university canteen produced, on average, 36 L/day of used cooking oil. The amount of biodiesel produced was 30.2 L/days, with 83.9% of yield. Using a diesel testing machine, biodiesel with B30 type (30% biodiesel and 70% diesel in volume) held the potential to generate electricity of 3,014 kWh/month. This value is expected to contribute to 12% of lighting in the Rectorate Building used for administration and official activities. Savings of IDR 3,348,857 can be achieved every month by substituting electricity sources into biodiesel. Furthermore, by considering biomass as sustainable renewable energy resources, a reduction in carbon emissions can be valued by 2.2 MTCO₂/month.

1. Introduction
Increasing energy consumption and the depletion of petroleum reserves in Indonesia have encouraged the government to carry out an optimal program of energy diversification. An average GDP growth rate of 6.04% per year and a population growth of 0.71% per year during 2016-2050 result in a final energy growth rate of 5.3% per year [1]. Therefore, to face the challenges in the energy sector as well as a form of energy diversification, it is necessary to exploit the potential of new and renewable energy. One of the renewable energy sources that have the potential to be developed in Indonesia is biodiesel.

Biodiesel is renewable, biodegradable, and non-toxic fuel, having relatively similar physicochemical parameters to those of diesel [2]. Biodiesel can be produced from a great variety of raw materials. These raw materials include the most common vegetable oils (e.g., palm, sunflower, soybean, cottonseed, rapeseed/canola, peanut, coconut, safflower) and animal fats (usually tallow) as well as waste oils (e.g., used cooking oils) [3]. To obtain biodiesel, fatty acid methyl esters (FAME), known as biodiesel fuel, are derived from triglycerides using the transesterification process. The main advantages of using biodiesel are its derivation from renewable domestic resources, less emission,
higher flash point, biodegradability, and excellent lubricity [3]. Therefore, biodiesel has been promoted and reported as a promising long-term renewable energy source which has the potential to address the emission of carbon dioxide (CO₂) to the atmosphere, security concerns, limitation of fossil fuels resources and the fluctuating prices of fossil fuels [4-7].

Used cooking oil is the leftover frying oil, originated from different types of oils such as corn oil, vegetable oil, and samin oil [8]. Due to its lower price, the use of such cooking oil for biodiesel brings economic benefits [9]. Although used cooking oil contains relatively high free fatty acids (FFAs), it still can be converted into biodiesel [9, 10]. In Indonesia, the annual used cooking oil utilization of 3,072,280 kL can potentially reduce greenhouse gas emissions by 11.5 million tons CO₂ per year [11]. Therefore, this high potential of used cooking oil in Indonesia can be used as a substitute for fossil fuel by converting used cooking oil into biodiesel.

Universitas Pertamina is a private university established in 2016. The university was founded with the spirit of becoming a world-class university in the energy field. It is reaffirmed by the commitment to its vision and mission by actively giving contributions to the world through science development and research in the energy technology field. To achieve the vision, the university highly encourages the promotion of new and renewable energy programs. One of the best shoots is by identifying the potential of waste to energy concept through biodiesel production based on the used cooking oil. This research aims to estimate biodiesel production as renewable energy from used cooking oil. Furthermore, estimation of the potential electricity generation from biodiesel production to support sustainable electricity programs at Universitas Pertamina as well as to support the government program of energy diversification was also performed.

2. Method
This study was conducted at the canteen at Universitas Pertamina, located at Komplek Universitas Pertamina, Jakarta. Field observations and literature reviews were also made. The research methodology is illustrated in Figure 1. The questionnaire was distributed to the sellers at the canteen. The questionnaire was aimed to gather information such as the amount of oil for cooking, used cooking oil production, and management of cooking oil. The field observations consisted of questions on the cooking activities, including the frequency of cooking oil replacement, treatment of cooking oil, cooking oil collection, and cooking oil disposal. There were 30 sellers using cooking oil, and one seller did not use cooking oil for cooking activity. The number of sellers using branded cooking oil was 25, and bulk cooking oil was 5.

| Table 1. Relationship between the yield of biodiesel produced and frequency of cooking oil replacement. |
|----------------------------------------------------------|
| Frequency of cooking oil replacement | Yield  |
|-----------------------------------|--------|
| 1                                 | 84.59  |
| 2                                 | 83.92  |
| 3                                 | 83.36  |
| 4                                 | 83.1   |
| 5                                 | 81.37  |

Source: Effendi et al, 2012 [12].

The conversion process of used cooking oil into biodiesel and the estimation of electricity generation were conducted through the literature review. Characteristics of biodiesel produced from the esterification-transesterification reaction of used cooking oil were influenced by the frequency of cooking oil replacement [12]. Efendi et al. [12] reported that the effect of the amount of used cooking oil on the yield of biodiesel produced decreased with the increasing frequency of cooking oil replacement. The relationship between biodiesel yield and frequency of cooking oil replacement can be seen in Table 1. Treatment for reducing high free fatty acids (FFA) requires twice the making biodiesel process. The first process is esterification using acid catalysts. Then, the second process is
transesterification using base catalysts. The esterification process is a reversible reaction where FFA is approved to become alkyl esters through acid catalysts (HCl or generally H\textsubscript{2}SO\textsubscript{4}) [12]. FFA levels can also be reduced by using the methanol esterification reaction with an acid catalyst. Esterification and transesterification reactions through acid catalysts can increase to get a perfect biodiesel conversion, which meets standard quality.

![Figure 1. Research framework of the production and utilization of used cooking oil-based biodiesel.](image)

This research used the measurement of Specific Fuel Consumption (SFC) biodiesel references to Ali and Nugroho (2017) by using a diesel testing machine with different biodiesel types [13]. SFC interprets the level of fuel consumption in producing power. The calculation of SFC values is shown in equation 1. Based on the previous study [13], the reported value of SFC for the B30 type was 0.2606.

$$SFC = \frac{m}{P}$$  \hspace{1cm} (1)

m : The level of fuel consumption (L)
P : Power generated (kWh)
SFC : Specific Fuel Consumption (L/kWh)

After the data of electricity consumption obtained from the Directorate of Facilities, Infrastructure, and Information Technology Universitas Pertamina, the electricity savings could be calculated.

3. Results and discussion

3.1. Collection of used cooking oil

The canteen at Universitas Pertamina consists of 31 sellers, selling various foods and drinks. 97% of sellers used cooking oil for frying activity, and 80% of sellers used branded cooking oil as compared to the bulk cooking oil. The amount of cooking oil purchased had an average of 2.94 L/seller.day, with a total of 91 L/day. The consumption of cooking oil was 2.65 L/seller.day, or around 90.1% became
waste cooking oil. Research conducted at Fatih University in Istanbul reported that there was 2,000 kg of used oil, and 1,600 kg or 80% became waste cooking oil [14].

The recapitulation of the questionnaire results is shown in Figure 2a. Whereas, the total production of used cooking oil was 1.16 L/seller.day with detailed production of used cooking oil is in Figure 2b. The frequency of cooking oil usage mostly showed more than two times a day (48.39%). The average repeats of cooking oil are two times reuse. The use of cooking oil with the reuse intensity at that level can be concluded that the used cooking oil is already at a sufficiently saturated level. It might be because cooking oil used has been reheated and produces saturated fats and substances that are harmful to health [15].

![Figure 2a](image1.png)  ![Figure 2b](image2.png)

**Figure 2.** Identity of oil used by traders (a) and used cooking oil production (b) from canteen at Universitas Pertamina.

![Figure 3](image3.png)

**Figure 3.** Response of sellers in managing the used cooking oil.

![Figure 4](image4.png)

**Figure 4.** Response of sellers in the treatments of used cooking oil.

The actions taken by sellers in managing used cooking oil are filtering (64.52%), disposing into containers (29.03%), disposing into trash bins (3.32%), and others (3.32%) (Figure 3). The treatments of used cooking oil by sellers are disposing into the dishwasher tub (6.45%), disposing into the gutter (6.45%), putting in a trash bag (41.94%), and selling the used cooking oil to collectors (45.16%) (Figure 4). Used cooking oil is usually sold to collectors for reprocessing and reselling [16].
Several campuses in Indonesia have conducted research related to the use of biodiesel for campus activities. At Andalas University, waste cooking oil is generated at 517.48 L/week and used for campus bus transportation [17]. Currently, research on the utilization of waste cooking oil in Indonesia is still very minimal, especially for the university canteen. Noor et al. mentioned that the utilization of waste cooking oil indirectly gives a real impact on the environment in reducing perspective pollution [18]

3.2. Conversion of used cooking oil into biodiesel fuel

The properties of used cooking oil can change depending on the frying conditions, such as temperature and cooking time. Thermal stress, such as during frying, can indeed vary chemical and physical characteristics of original cooking oil. The thermal stress during the frying process causes the triglyceride to break down to form diglycerides, monoglycerides, and free fatty acids [19]. The high-level FFAs in used cooking oil resulted in accelerating some undesirable side reactions during biodiesel production [20, 21]. Therefore, the used cooking oil was initially pre-treated with a mineral acid to reduce FFAs [22] and then subjected to base-catalyzed transesterification for biodiesel production.

During pre-treatment, the used cooking oil was mixed with methanol and a mineral acid such as HCl, H2SO4, and H3PO4 at specified reaction temperature and time. The mixtures were then centrifuged to separate methanol and used cooking oil. The pre-treated used cooking oil was subsequently washed with deionized water and subjected to the transesterification process for biodiesel production.

Transesterification of pre-treated used cooking oil was carried out in the presence of base catalyst [23, 24]. The pre-treated used cooking oil was added to the batch reactor containing KOH and methanol. Transesterification produced glycerol and fatty acid methyl ester (FAME), which is biodiesel. During the process, triglycerides were converted to diglycerides, monoglycerides, and glycerol consecutively. The ratio of methanol to oil, catalyst dose, reaction temperature, and time has been reported to influence the transesterification process [25, 26]. Based on the data of frequency cooking oil replacement, the final amount of biodiesel obtained from this study was 30.2 L/days with 83.9% of yield.

3.3. Estimation of the electricity generation from biodiesel fuel

According to the previous study, B30 has a smaller heating value than diesel fuel oil. The small heating value causes an increase in fuel consumption, which aims to maintain its power. For the B30 type, the SFC value is 0.2606 [13], the volume of biodiesel fuel produced is 30.21 L/day, and the power generated is 115.93 kWh/day or 3,014 kWh/month. When compared with other studies on solar, B20, and B40 [27], it generated electricity at 2,698.35 kWh/month; 2,595.81 kWh/month; and 2,554.44 kWh/month. A comparison of electricity production by biodiesel is given in Figure 5.

The use of the B30 type is also an effort to support the 30% Biodiesel Mandatory Program (B30) Minister of Energy and Mineral Resources Regulation No. 12 of 2015 [28]. Based on the Minister of Energy and Mineral Resources Regulation No. 12 of 2015, the types of sectors required to implement are micro-businesses, fisheries businesses, agricultural businesses, transportation, and Public Service Obligation (PSO); non PSO transportation; and industrial and commercial. However, the program has been implemented well in the Public Service Obligation transportation sector. The use of biodiesel has not yet reached the commercial sector, such as universities. Nowadays, the use of B20 has been found to produce low emission [29]. Although B20 is considered low emissions, the use of B30 to B100 also has a lower emission impact.

The pattern of emission reduction in percentage shows that the higher the level of biodiesel content in fuel, the more reduced the transportation emissions resulted. The use of biodiesel has low SO2 emissions because pure biodiesel usually contains low sulfur [30-34]. The efficiency reduction of the environmental impact emissions using biodiesel follows SO2 (10-100)%; NOx (1–9)%; HC (10–68)%; PM (4–45)%; CO (6–48)%; and CO2 (6–31)% [30].
3.4. Utilization of biodiesel to support electricity in Universitas Pertamina

Biodiesel production was further used to generate electricity, as mentioned in the previous discussion. In this section, the amount of electricity based-biodiesel contributed to the electricity consumption at Universitas Pertamina was calculated. The electricity consumption at the building of Universitas Pertamina is mainly divided into equipment and lighting. Based on the electricity consumption data from the Directorate of Facilities, Infrastructure, and Information Technology, Universitas Pertamina, the monthly average of electricity consumption for the lighting of the Rectorate Building in 2017 was 25,523 kWh (Figure 6). Biodiesel production was able to produce as much as 3,014 kWh/month of electricity, meaning that the biodiesel production was able to contribute around 12% electricity supply of Rectorate Building lighting. The saving benefits per month from the applied system are around IDR 3,348,857 based on the average electricity pricing charged to the lighting of the Rectorate Building in 2017 by IDR 1,111/kWh.

Moreover, since the biodiesel was biomass-based, which has been categorized as sustainability sources, the reduction of greenhouse gas emission through the CO₂ emission could be estimated. Universitas Pertamina is located in Jakarta, Java Island; hence the emission factor for electricity follows the interconnection system of Jawa–Madura–Bali. The emission factor is 0.741 kg CO₂/kWh [35]. Finally, the reduction of CO₂ emission could be calculated by multiplying the total kWh generated from biodiesel by 0.741 kg CO₂/kWh, which is equal to 2.2 MTCO₂/month.

4. Conclusion

The estimation of biodiesel production from used cooking oil received from the university canteen as an alternative resource for producing biodiesel fuel has been conducted. This research showed that through the transesterification process, the concept of waste to energy by converting used cooking oil
into biodiesel fuel had been potentially well performed. The used cooking oil could be obtained by 36 L on the daily average, which resulted in 30.2 L/days on the yield of 83.9% of biodiesel fuel. B30 type of biodiesel was potentially able to generate electricity of 3,014 kWh/month tested by a diesel machine. When the electricity-based biodiesel applied to light in the Rectorate Building, it potentially contributed by 12%, giving saving benefits of IDR 3,348,857/month. Besides, the use of biodiesel fuel is appraised to cut the carbon emission by 2.2 MTCO2/month. The utilization of biodiesel as a renewable energy alternative has a great impact to substitute fossil fuel by providing both economic and environmental benefits.

5. References

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